NUCLEAR ENERGY

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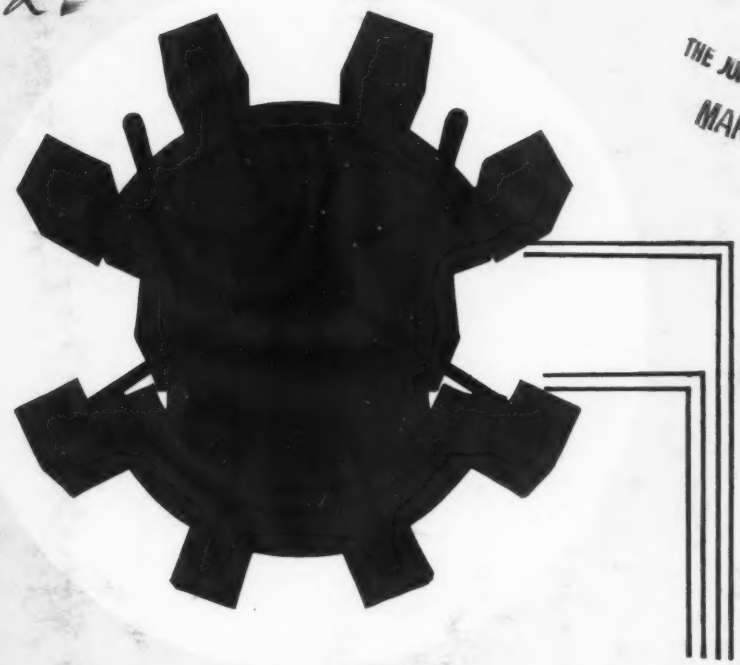

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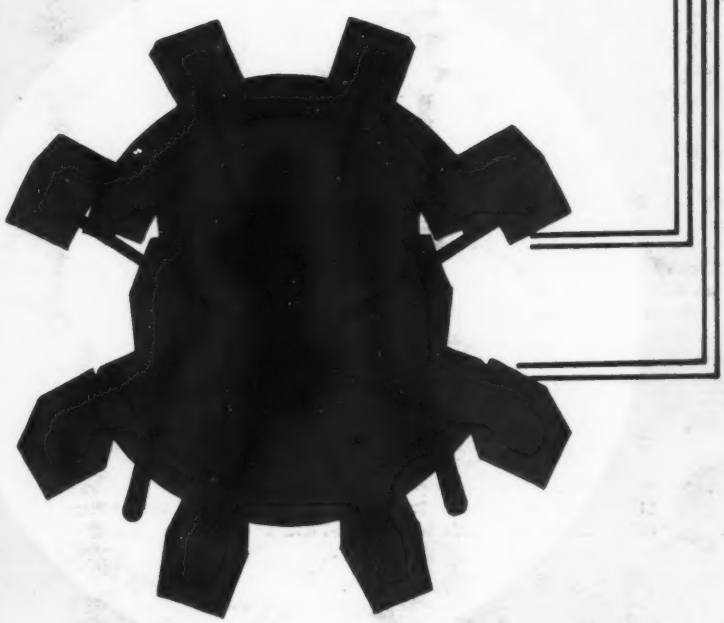

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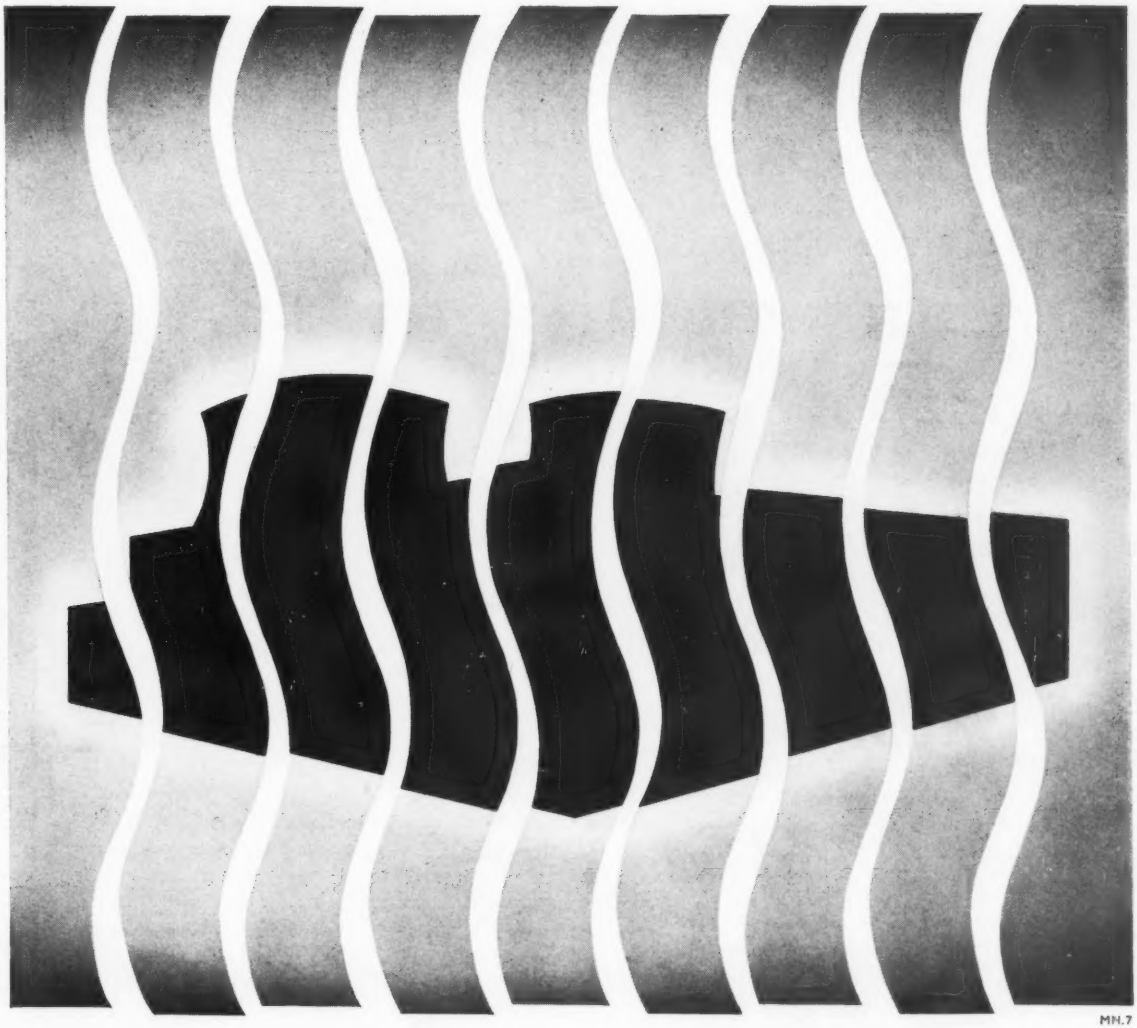

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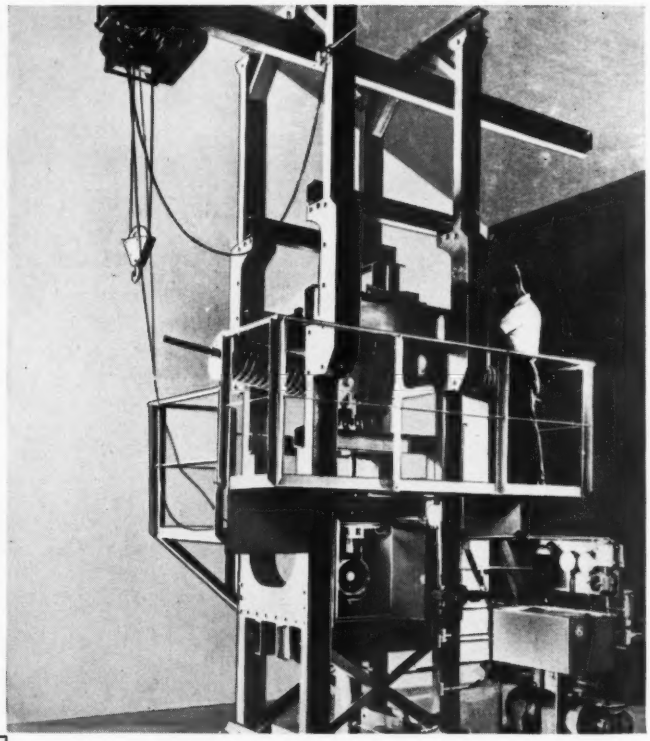

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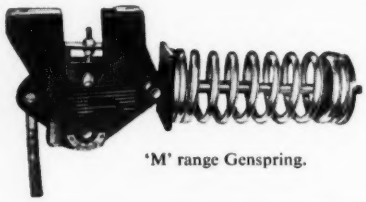

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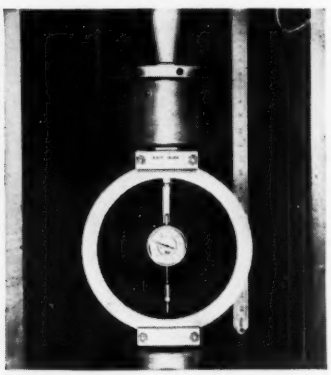

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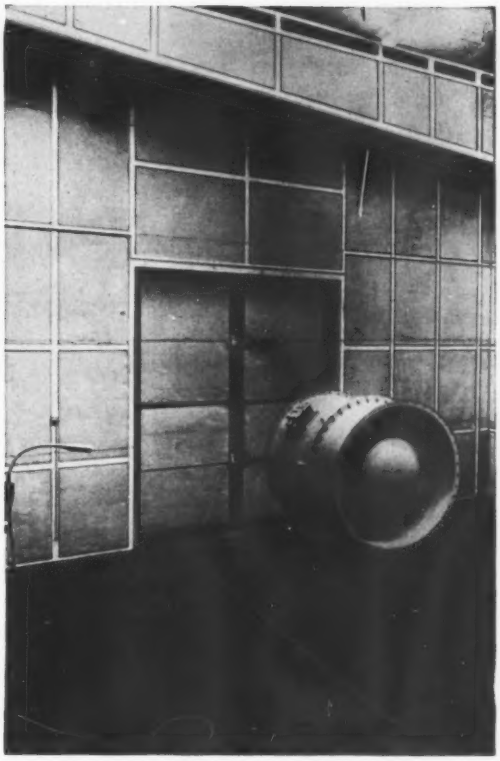

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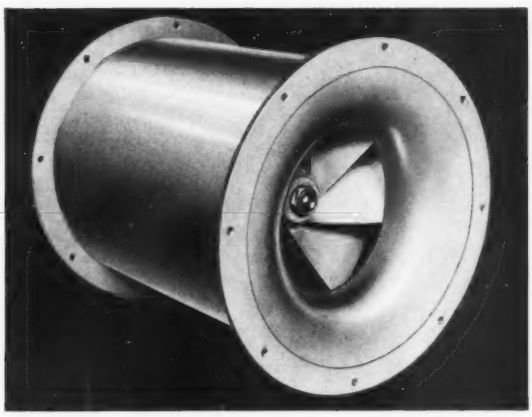

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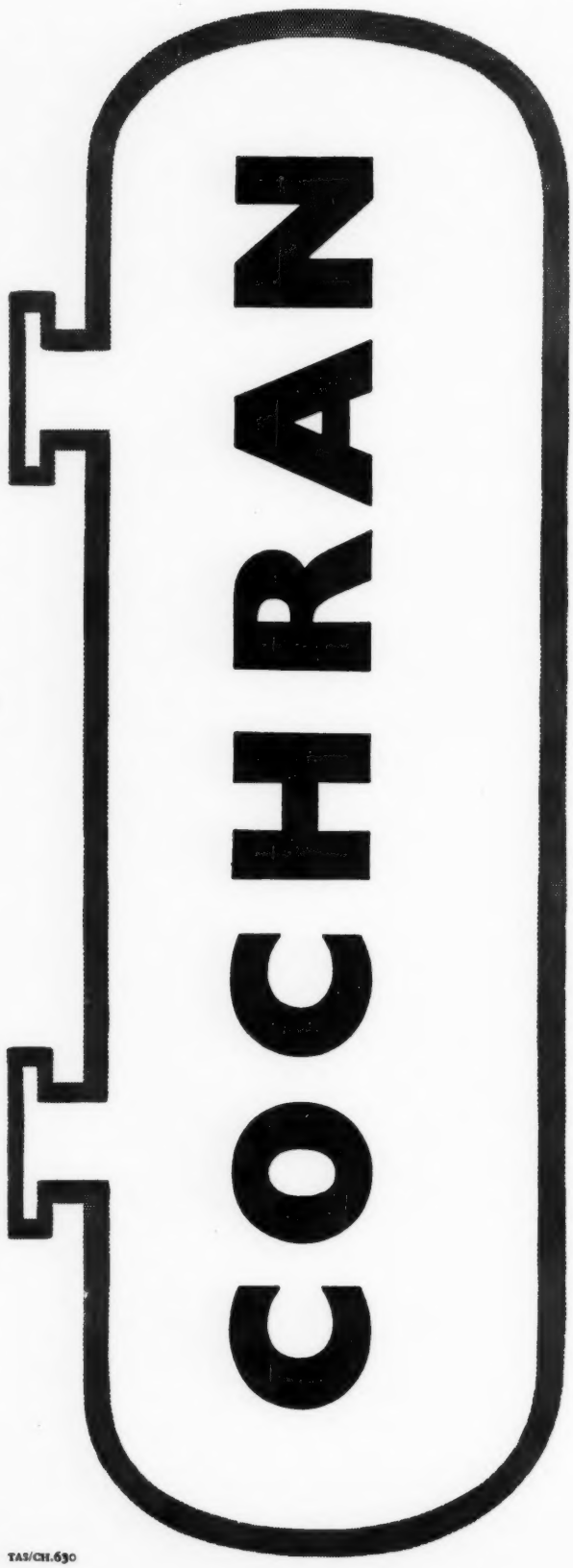

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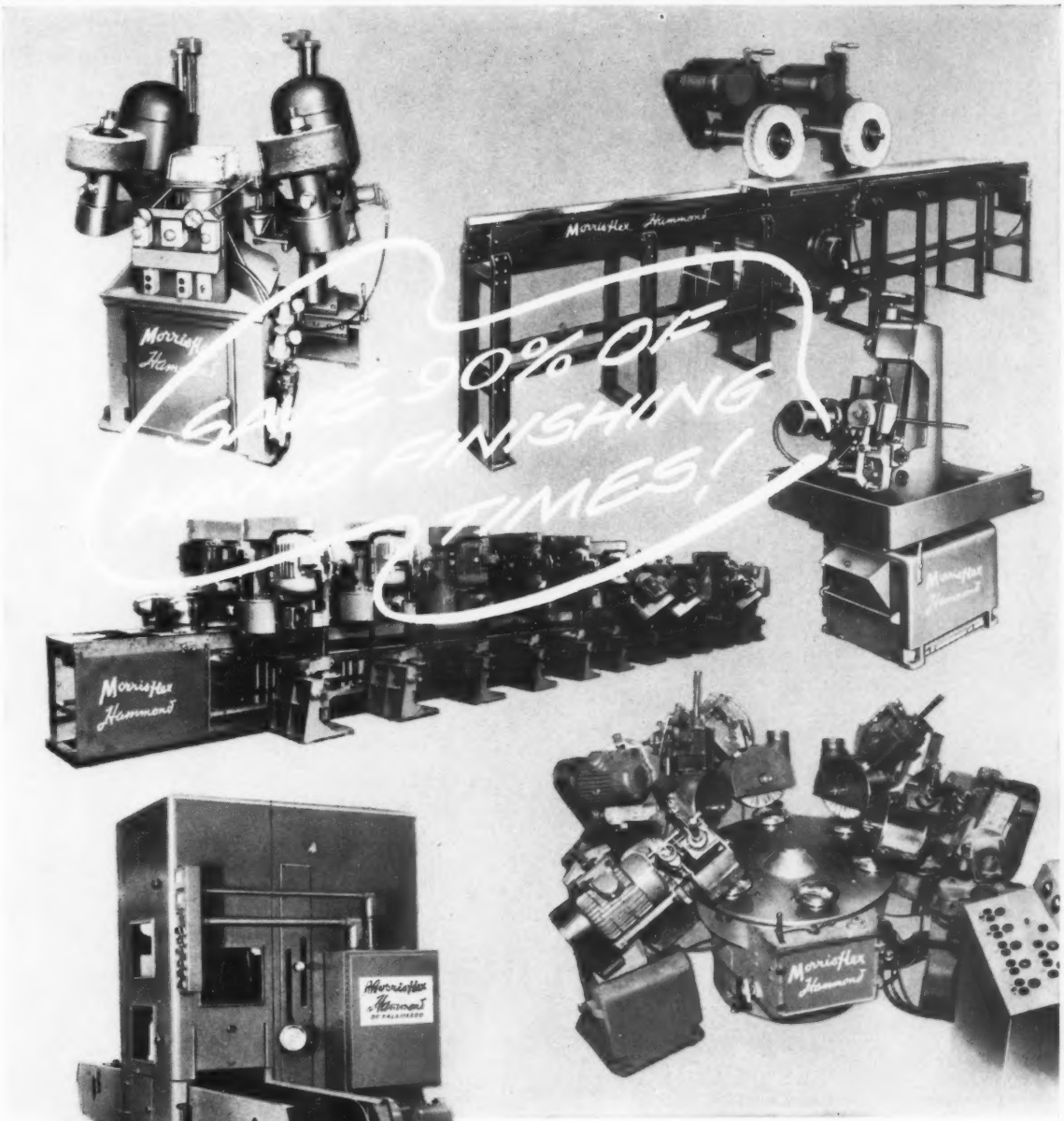

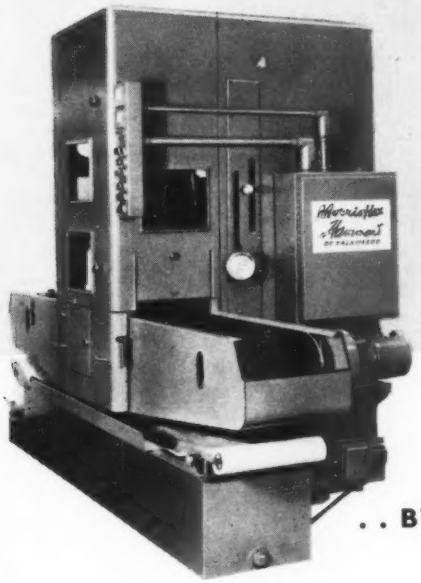

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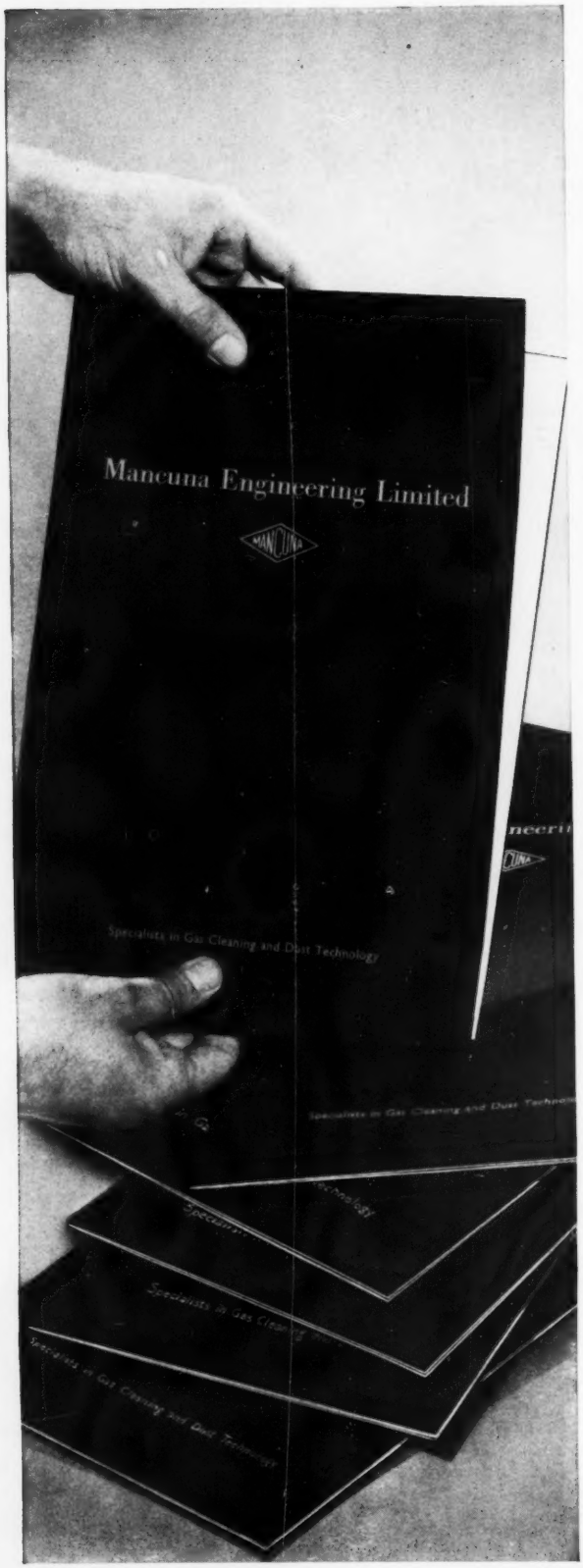

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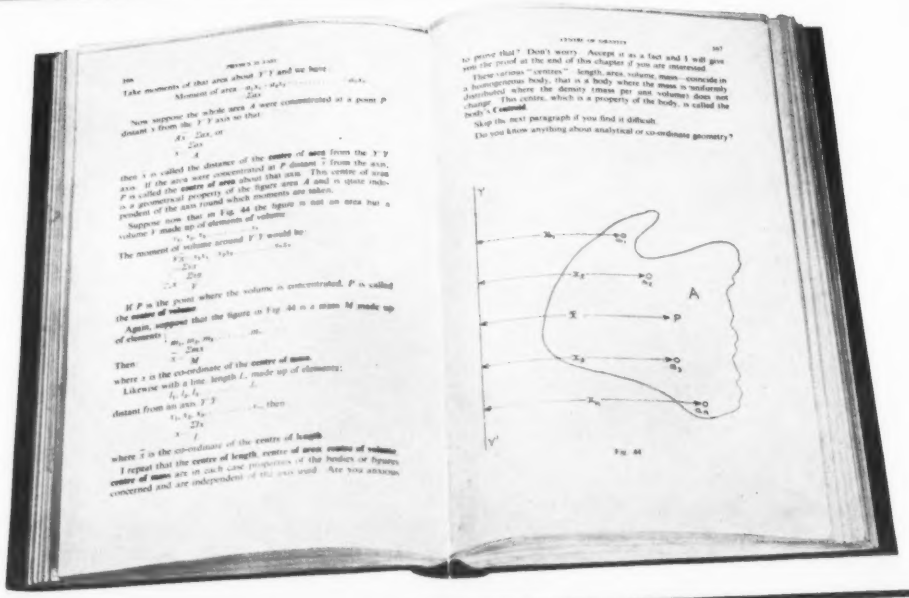

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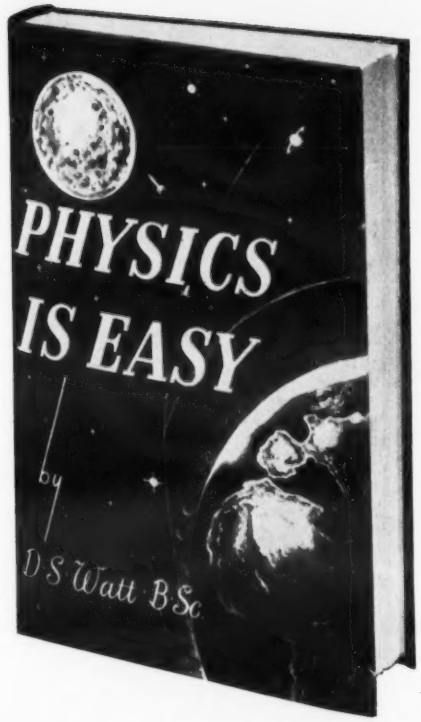

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NUCLEAR ENERGY ENGINEER

Vol. 13 No. 130

MARCH, 1959

CONTENTS

PAGE

Economic Aspects of the United Kingdom's N-Power Programme—Part II, by J. C. Duckworth and Hywel Jones 129

SNAP III—The Isotope Generator 131

The AWRE Reactors — HORACE and HERALD 132

Battersea College of Technology 136

Progress at Berkeley 140

Concrete for Biological Shielding, by A. L. Brake, AMIStructE 142

Springfields—UKAEA Uranium Fuel Factory 146

Concrete Pressure Vessels—Part II, by J. Bellier and M. Tourasse 150

Laboratory Research Reactor 151

People in the Nuclear News 152

Heat Into Electricity 153

Hungarian Newsletter 154

Nuclear Energy Developments in Europe—Russia and Poland, by J. Burkett .. 155

Nuclear News 157

Nuclearist Writes 160

Projects ROVER and PLUTO 161

Equipment and Materials 164

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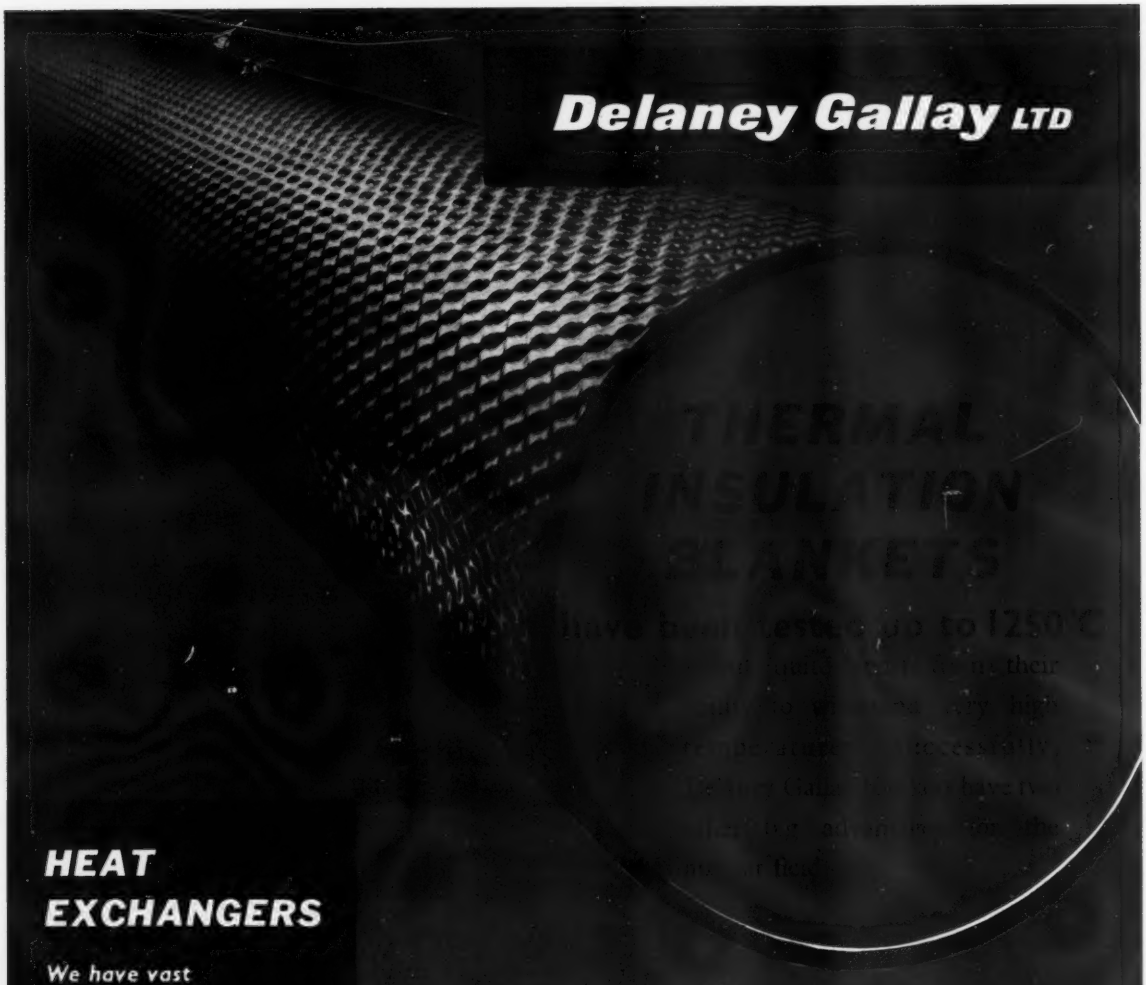

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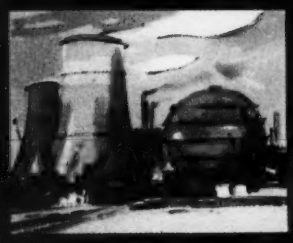

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Economic Aspects of the U.K. N-Power Programme*

PART II

by J. C. DUCKWORTH, and E. HYWEL JONES

(*Continued from page 112*)

IN last month's article it was demonstrated that on economic grounds alone the introduction of a number of nuclear power stations into the United Kingdom electricity supply system should be fully justified. After taking into account the non-flexible plant in the system the remaining base load available for "order of merit" running in 1965 is expected to range from about 6,500 MW on a summer week-day to some 8,500 MW on a winter week-day, but may well be as low as 4,300 MW on a summer week-end. It is reasonable to assume however that the major portion of the planned outages will arise during the summer months and taking this into account it will be possible to operate some 7,000 MW of nuclear plant at 75 per cent. load factor or above in that year.

The rate of increase of base-load in the last half of the 1960 decade will be about 400 MW per year, so that even if nuclear plant is only competitive with the latest conventional plant in these years at load factors of 75 per cent. or above, the nuclear installation rate could still be at least of that order of magnitude.

Disadvantages Decreased

For a higher installation rate of nuclear plant after 1965 it would necessarily have to be competitive at lower load factors. As discussed last month this situation will be brought about in the higher coal cost areas, so that a rate somewhat greater than the overall increase in base-load can be assumed. Moreover, the decrease in capital costs per kilowatt will reduce the disadvantage of nuclear plant at the lower load factors. However, the desirability of a good overall load factor, evident enough in all supply systems, will be strengthened for many years to come by the advent of nuclear plant.

Trends in nuclear fuel costs will also have an important bearing on nuclear planning. If, as has been the trend with conventional plant over a number of years, fuel costs decrease as development proceeds, then each new station heads the "order of merit" of stations (order of increasing operating cost) and after completion is operated at maximum availability. Older nuclear stations must then operate at lower load factors, if there is nuclear capacity in excess of the base-load. Development of more highly rated reactors, however, with consequent lower capital costs, might be associated with higher fuel costs if the cost of enrichment is not counterbalanced by longer mean irradiation times. In this case new stations might have to operate immediately after completion at lower load factors. In either case the economics of the system as a whole has to be investigated for all possible installation programmes, bearing in mind the load factors of operation over their whole anticipated lifetimes of each component of the system, before the most economical planting programme can be decided. A simple comparison between individual types of nuclear and conventional plant at any one load factor of operation is not sufficient.

Energy Storage

Improvement in overall load factor is primarily a matter of encouraging demand at off-peak periods. However, the same effect can be achieved in the generation system by the application of energy storage methods. A load duration curve, on a yearly basis, for a purely thermal system is shown in Fig. 1. Plants having low running costs occupy the lower part of the curve and carry the bulk of the load. The middle portion of the curve is occupied by older machines running on less advanced cycles and at lower load factors. Peak loads, at the top of the curve,

*Paper presented at 2nd International Conference on the Peaceful Uses of Atomic Energy.

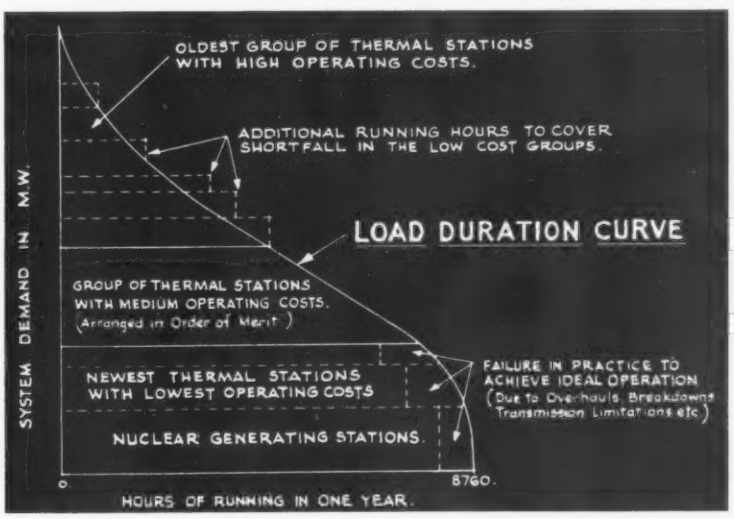

OLDEST GROUP OF THERMAL STATIONS WITH HIGH OPERATING COSTS.
ADDITIONAL RUNNING HOURS TO COVER SHORTFALL IN THE LOW COST GROUPS.
LOAD DURATION CURVE
GROUP OF THERMAL STATIONS WITH MEDIUM OPERATING COSTS. (Arranged in Order of Merit)
NEWEST THERMAL STATIONS WITH LOWEST OPERATING COSTS
FAILURE IN PRACTICE TO ACHIEVE IDEAL OPERATION (Due to Overhauls, Breakdowns Transmission Limitations etc.)
NUCLEAR GENERATING STATIONS.
SYSTEM DEMAND IN M.W.
0
8760.
HOURS OF RUNNING IN ONE YEAR.

Fig. 1.—Load duration curve for thermal system

are carried by old " time expired " plants with complete economic justification, even when their running costs are as high as 1.5d. or 2.0d. per unit, owing to the short duration of the peaks.

Effect of Pumped Storage

The effect of introducing pumped storage into the scheme is shown diagrammatically in Fig. 2. Basically a means is provided for pumping large masses of water from a low level reservoir to a higher one. This is done at the light load periods and helps to fill the valleys in the load curve. At peak load periods the process is reversed and the " head " of water in the high level reservoir is used to generate electricity. In practice, there are refinements to this simple system, in order to utilize the additional pumping periods available at week-ends. The diagram in Fig. 3 explains this method.

The shape of the 24 hr load curve will determine the maximum pumping period, and during mid-week this may be assumed to be 7½ hr/night. Allowing for the efficiencies of the component parts of the scheme as follows:—

	Per cent.
Motors	97.5
Pumps	85.0
Aqueducts (up and down) ..	96.0
Water turbines	90.5
Generators	97.5

the overall efficiency for the full cycle will be about 70 per cent.

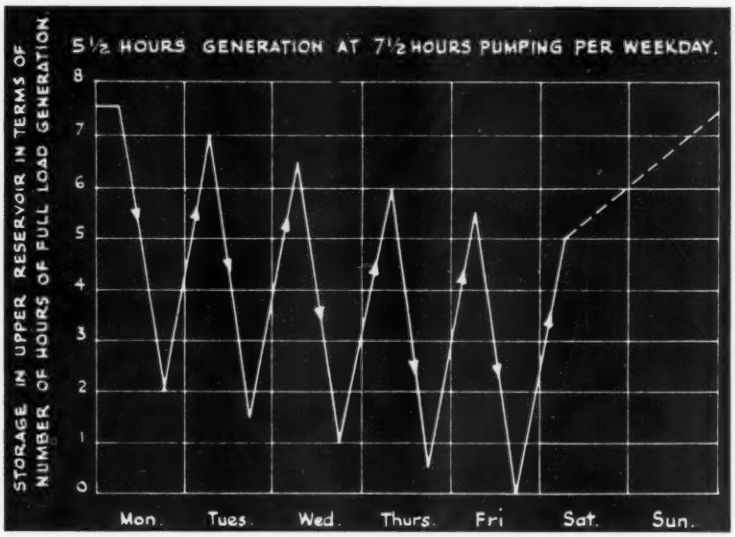


Fig. 3.—Storage in upper reservoir in terms of hours of generation

Whilst actually generating the sets may not always be running at the most efficient load (due to variations in load at the beginning and end of the generating period) so the average overall efficiency at the power station end will be, say 66/69 per cent.

Fifty per cent. Increase

In effect, for a full load pumping period of 7½ hr, full load generation is possible for a little over 5 hr. By utilizing the extra pumping hours available at week-ends and running down the storage capacity of the reservoir as shown in Fig. 3 a slightly longer period of generation is possible each week-end (say 5½ hr). It will be clear, however, that the fuel cost of pumped storage units will be increased in the ratio 100:66 (say a 50 per cent. increase) compared with the fuel cost of a direct supply from the generating station.

The operating costs of a combined conventional steam generation and pumped storage scheme are therefore no better than those of medium merit steam plant working on its own, and they may be expected to increase significantly with the price of coal. Bearing in mind the capital cost of pumped storage plant, it seems a safe conclusion that the economics of pumped storage in relation to future steam plant will be doubtful. Used in conjunction with nuclear plant, however, with fuel replacement costs of the order of 0.13-0.19 pence/unit sent out the pumped storage plant can return units to the system at an equivalent fuel cost of 0.2-0.3 pence/unit, at times when they would otherwise be provided by steam plant with higher fuel costs.

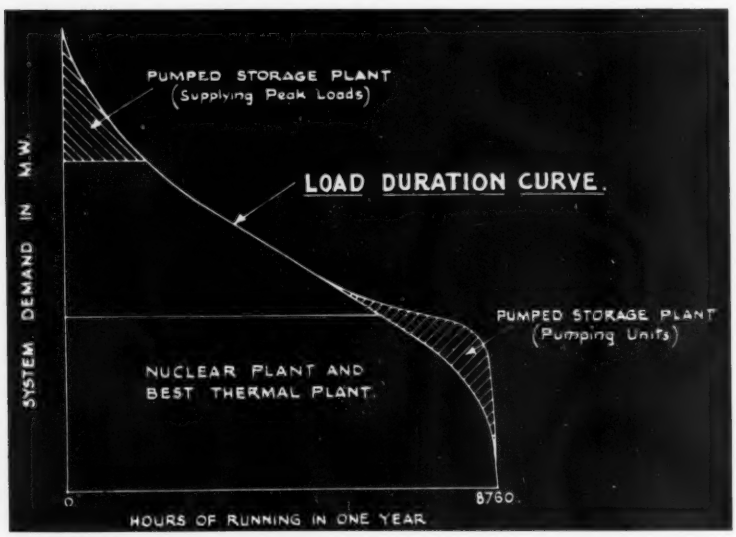


Fig. 2.—Effect of introducing pumped storage

Storage Costs

Capital costs for pumped storage plants are difficult to assess in general terms as they vary widely between one site and another. The Ffestiniog scheme in North Wales, with a capacity of 300 MW is estimated to cost £15m. without transmission, or £50/kW. A 300 MW scheme for the South of Scotland

Electricity Board in the Galloway Area was estimated to cost £51/kW. The Loch Awe Scheme for the North of Scotland Hydro-Electric Board, which consists of 400 MW of pumped storage plus 50 MW of normal hydro-generation is estimated to cost £24.5m. without transmission, or £54.5/kW. Assuming a figure of £150/kW for the 50 MW of normal generation, the cost of the pumped storage capacity is £42.5/kW. (At £100/kW for normal generation, the corresponding figure would be £49/kW for pumped storage).

Sites Limited

On capital cost, therefore, pumped storage has little in its favour compared with conventional steam plant. More favourable sites may reduce the cost of the civil engineering but possibly at the expense of the transmission system. The present cost of heavy duty (2×0.4 sq.in. conductors per phase) double circuit 275 kV transmission line may be as high as £30,000/mile and this together with the problems of ensuring system stability will limit the choice of sites.

The plant capacity installed in the form of pumped storage does, however, provide a very convenient means for dealing with peak loads provided the generation hours are not less than the duration of the peak loads themselves. The plant is available at short notice and very rapid load changes are possible.

A Good Case

Used in conjunction with low operating cost nuclear plant such as is envisaged in the U.K's initial nuclear programme, a good case could be made out for pumped storage schemes where power generated from the nuclear plant is surplus to base load requirements. The number of installations will be limited by the availability of suitable sites, and later by the possible development of reactor types (previously referred to) which may be more suitable for running at lower load factors. Under these conditions a very large capacity of pumped storage plant would not be needed.

The current series of graphite moderated nuclear reactors are given a life of 20 years for the purpose of capital amortization. The civil works associated with hydro-electric schemes are usually written off very slowly over a period of 60-80 years and the moving plant over a period of 35 years, both of which periods are much greater than the comparatively short "life" of nuclear plant. It is possible, therefore, as a result of nuclear developments, that an excessive capacity of pumped storage plant would cease to be economically useful, long before the full life of its civil works was reached.

Difficult Prediction

The case for the installation of a considerable amount of nuclear plant in the next decade has been demonstrated, together with associated pumped storage schemes. The present trends in nuclear generation costs indicate that over the following period the optimum proportion of nuclear plant in the system is likely to increase. The type of nuclear plant, and the extent of associated development such as pumped storage schemes after the next decade, are more difficult to predict, and depend in particular on the trend in nuclear fuel costs.

The authors wish to acknowledge assistance from Mr. P. S. K. Eaves in the preparation of some of the figures used in this article.

SNAP*-III—*the isotope reactor*

THE prime contract to design and fabricate SNAP-III, the radioisotope-fuelled thermoelectric generator unveiled at the White House recently, was awarded to the Nuclear Division of The Martin Co. by the U.S. Atomic Energy Commission in April, 1958. The aim was to produce a device combining a radioisotopic heat source with a direct energy conversion system, determining and demonstrating the feasibility of this principle.

Martin awarded four separate subcontracts for the energy conversion system, and the first SNAP-III demonstration device, using thermoelectric conversion components manufactured by Minnesota Mining, was delivered to the A.E.C. on January 13th, 1959. Work by other subcontractors is continuing.

SNAP-III weighs only 5 lb. It is in the shape of an elongated spheroid with a diameter of 4¾ in. and a height of 5½ in. In output it is capable of delivering 2,900 watt-hours/lb over a period of about 280 days (two half-lives of Polonium-210, the isotope used). This energy is equivalent to the power produced by more than 1,450 lb of nickel-cadmium batteries.

The principles underlying SNAP-III are fairly simple. The energy liberated in the spontaneous decay of the radioisotope raises the temperature of the metallic core and container surrounding it, and this "hot junction" temperature starts the movement of electrons. Twenty pairs of semi-conductor thermoelectric conversion elements extend like spokes from the centre to "cold junctions" along the inside of the outer wall. These elements, which are lead telluride rods alternately doped to produce an excess or a deficiency of electrons, are connected in series between the hot and cold junctions.

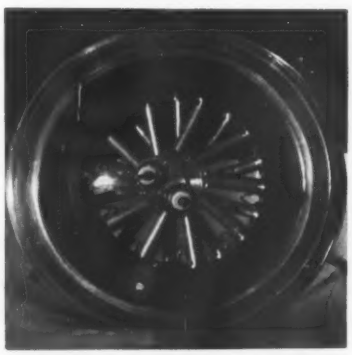
A Seebeck electro-motive force is generated between the hot and cold junctions, thus creating usable electrical energy. The total electrical output of the device, loaded with one-half of the isotope charge for which it was designed, is 2.4w.

Other Isotopes Possible

Polonium-210 (half life—138 days) was used in this demonstration model because of the very low gamma radiation associated with the alpha decay. A variety of other isotopes (including certain waste products of nuclear fission) could be used, and some would substantially increase a unit's lifetime. Cerium-144, for example, has a half-life of 290 days, or about twice that of polonium. Strontium-90 has a half-life of 28 years; plutonium-238 offers a 90-year half-life. Using such advanced fuels, a power source could be designed with a relatively small increase in weight and a very large increase in the total number of watt-hours/lb. The use of some of these materials would probably necessitate additional shielding during handling.

Although this particular device was not designed for inclusion in a satellite, a device of this general type using an isotope other than polonium could be used to power a satellite transmitter for extended periods. Units could also be used in remote weather stations, air-lane marker and warning beacons, navigational buoys for sea lanes, and a host of other applications.

Subsystem Nuclear Auxiliary Power.



View from above of cutaway model of SNAP-III. Another picture is on page 159

The AWRE Reactors

HORACE and

HORACE is a low powered experimental reactor designed for the investigation of the future operation and use of HERALD, the 5 MW reactor which is nearing completion at the Atomic Weapons Research Establishment. Various arrangements of fuel and reflector elements can be built up in it and the reactor allowed to go critical at a power of about 10 watts.

Being Investigated

The reactivity of different fuel loading for the larger reactor and the possible use of beryllia and aluminium fuel reflector elements are being investigated and optimum core loadings determined. Control safety is also being checked.

No Special Cooling

HORACE is, in fact, a simple light - water - moderated nuclear reactor incorporating fuel elements and spare equipment ultimately intended for HERALD. Since the power level is restricted to about 10w the flux density is sufficient for the operation of neutron counting and control instrumentation. The heat generated however, can be dissipated by natural convection of the water surrounding the core without the necessity of expensive pumping and cooling plant.

The water provides moderation, cooling and shielding and is contained in a 12 ft diameter tank sunk 15 ft below ground. This will eventually become the used fuel store for HERALD.

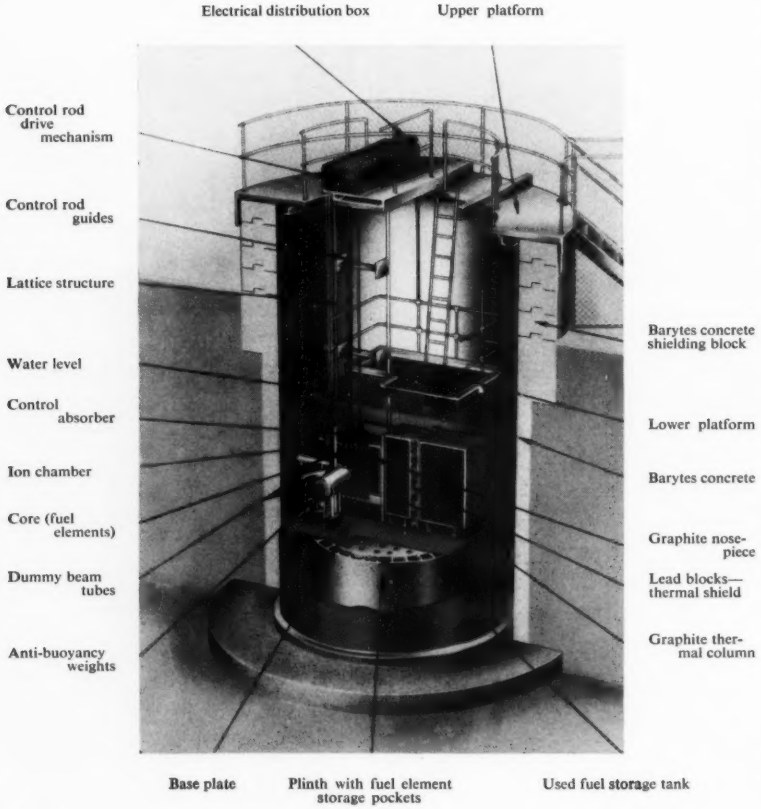
Dummy beam tubes and sections of the graphite thermal column, lead shielding and aluminium flume surround the fuel elements to simulate the core of the reator and provide a true picture of the flux pattern. Means are provided for heating the water to about 65°C. in order to determine the temperature coefficient activity of the core.

During the loading of the fuel elements, detection instruments record the neutron flux at various positions in and around the core. A graph is plotted during this operation showing the reciprocal of neutron counts against the mass of fuel loaded. Extrapolation of this curve gives an estimate of the critical mass of the core for any particular configuration before the assembly is made critical.

Different Arrangements

Core loadings are repeated using different arrangements of fuel and reflector elements, in order to optimize values of fast and thermal neutron fluxes for the various experimental ports which will be available in HERALD.

Peculiarities of control and instrumentation can be investigated and since HORACE is similar in design to HERALD, it is also used as a training facility for the physicists and engineers who will utilize and operate the larger assembly.

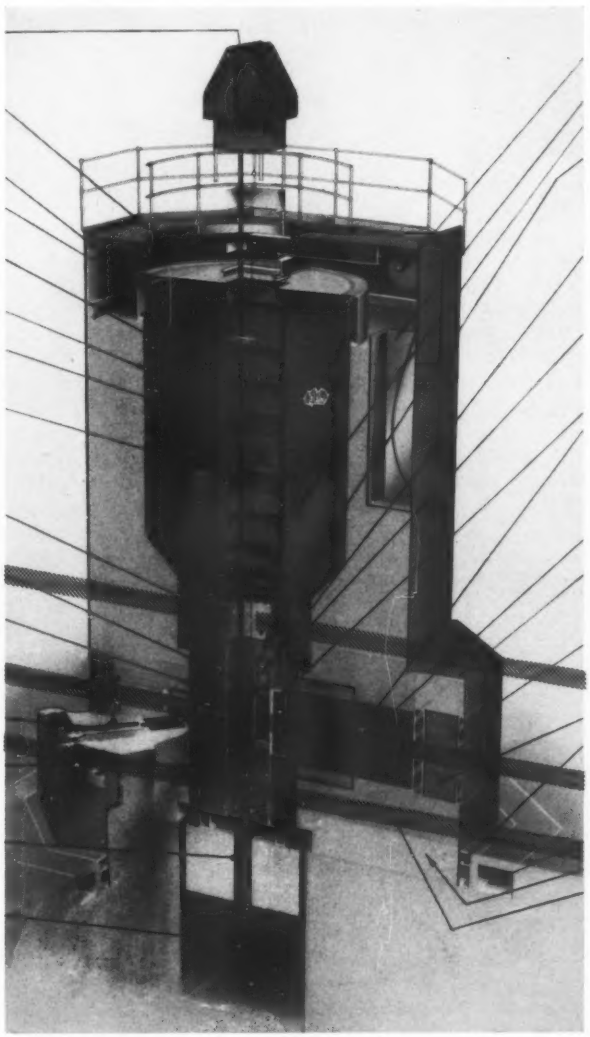


(*Left*) **Vertical section through the AWRE research reactor HORACE, which is being used for investigation of the future operation and use of the 5 MW reactor HERALD**

HERALD

HERALD is a light water moderated and cooled reactor using highly enriched fuel and designed to operate at a power of 5 MW. Based on an adaptation of the MERLIN reactor design, it is being built at the Atomic Weapons Research Establishment, Aldermaston, by the AEI-John Thompson Nuclear Energy Co., Ltd., who are responsible for its design in close collaboration with the AWRE. Construction work is expected to be shortly completed.

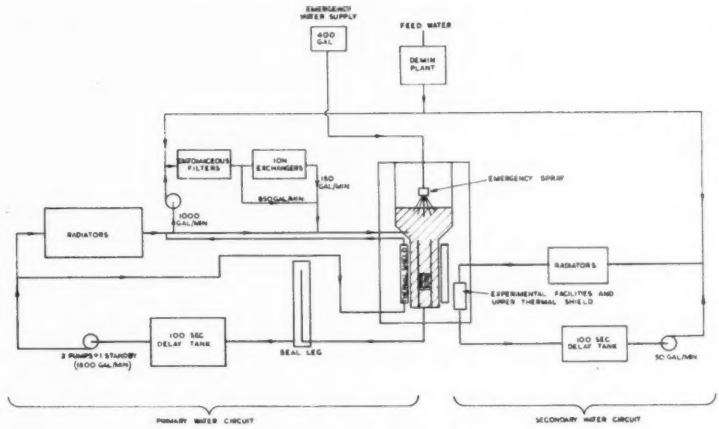
The primary function of HERALD will be to provide intense beams of thermal and epithermal neutrons for general nuclear physics experiments and experimental regions of high neutron flux for the irradiation of small samples to be used in radiochemical research. In addition it will be required to meet general but as yet less specified needs.



Vertical section through the 5 MW reactor HERALD. Three positions of the reactor core, which can be moved up and down by means of an electrically driven hoist, are shown by the three red lines. Top position is loading position, centre, operating position and the bottom, storage position

The design of the reactor has included a number of special features, which allow maintenance to be extended to the maximum number of components and which increase the safety of the reactor.

The core of the reactor consists of aluminium alloy fuel elements distributed in a 7×4 array surrounded by beryllia or aluminium reflector elements. Each fuel element contains 161 g of U-235 and is made up of 14 fuel plates of the type which has now become conventional in this sort of research reactor.



Reactor cooling circuit

Connected to Hoist

The core structure is suspended by two stainless steel wire ropes from a motor driven hoist placed at the top of the reactor tank. A square aluminium flume provides lateral stability and directs the coolant water through the core.

There are three normal positions of the core. In the middle position the core is opposite the experimental beam tubes. The upper position is a non-operating position allowing the core to be brought closer to the water surface to ease handling problems during fuel element changes. The lower position is a storage position which can be used in the event of damage to a beam tube, resulting in escape of water from the tank. A seal leg prevents the water falling below a level 6 in. above the core should water leak from any of the components or piping beyond the seal leg.

The reactor is controlled by four neutron absorbers which move vertically in water gaps between rows of elements. There are two safety absorbers, a single coarse absorber and a single fine control absorber. The safety and coarse control absorbers are of identical cruciform construction consisting of cadmium sheet sheathed in stainless steel, each controlling approximately 5.5 per cent. reactivity. The fine control absorber is a flat sheet of stainless steel controlling about 0.5 per cent. reactivity.

Control Drive

The control absorbers are actuated through rack and pinion drives by motors mounted on the core structure. The drives to the safety and the coarse absorbers are through magnetic clutches which are placed below the water surface. When the magnetic clutches are de-energized the fall is spring assisted so that the initial acceleration is greater than 2 " g ". The absorbers are brought to rest by water-operated shock absorbers placed below the magnetic clutches.

Manual Start-Up

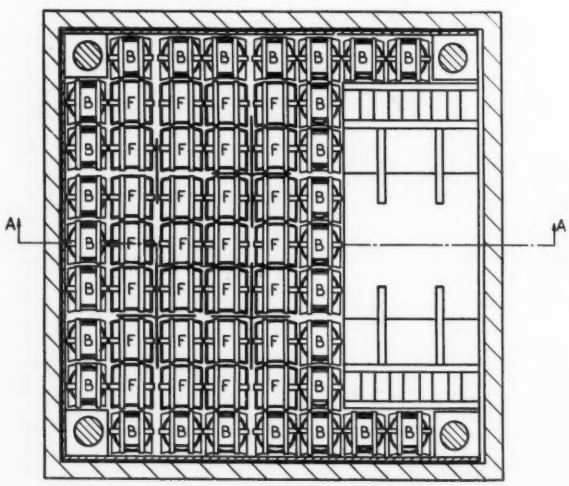
Operation of the HERALD is from a control room at the side of the reactor hall, overlooking part of the experimental floor area. All important reactor controls and instrument indications are brought to this room.

Start-up of the reactor and change of reactor power is accomplished by manual control. Operation at constant power can be made automatic by the use of a servo control system which regulates the position of the fine control absorber.

Six ion chambers and two fission chambers provide instrumentation of the reactor. Three of the ion chambers feed the excess power shutdown amplifiers and are mounted above the core in lead shields attached to the moving structure. The other three ion chambers feed the linear and two logarithmic power measurement channels and are close to the thermal column. They operate only when the core is in the experimental position.

Fission Chambers

One of the fission chambers, mounted on the moving structure, is for monitoring the core when it is in the experimental position and the other, which is fixed, monitors the core when it is in the loading position.



Plan of reactor core HERALD. F represents the fuel elements and B the blanking elements

The ultimate safety device is considered to be the excess power shut-down channel and therefore even under maintenance conditions two of these three channels will always be alive.

The two logarithmic power channels operate reactivity trips and doubling time meters. The linear channel feeds the servo system controlling power level and a deviation or power error meter. The fission chambers cover the power range from shut-down to 10w and initiate shut-down trips if the power exceeds this level before the two logarithmic channels come into operation.

Shut-Down Process

When the reactor power rises above about 40w the fission chamber which moves with the core is automatically withdrawn to a region of lower flux, in response to a signal from one of the logarithmic amplifiers. Conversely, when the power falls below 40w this fission chamber is automatically returned to the position of maximum response. A shut-down power greater than 1MW is ensured by attaching antimony-beryllium neutron sources to the lower end of each fuel element.

The reactor shielding is designed to provide a low radiation background in the experimental area surrounding the reactor. Low background in practice will also depend on the efficient shielding of experimental equipment beyond the beam tubes.

Radiation Shielding

The main biological shield is designed to reduce radiation levels to less than 1/cm² sec for fast neutrons and less than 1mv/h for gamma rays. At the level of the core the reactor tank is 5 ft 6 in. in diameter. The shield around the tank takes the form of 4 in. of lead thermal shield, 2 ft of iron shot concrete, of density 5.6 g/cm³, and 4 ft of barytes concrete, of density 3.5 g/cm³. The thermal shield is constructed from high purity lead cast in aluminium segments with duplicate aluminium cooling pipes in the lead.

No Entry

In the experimental position the depth of water above the centre line of the core is 22 ft so that direct radiation from the reactor core at the top of the reactor tank is below the biological MPL. However, due to recoil of nuclei from the fuel elements, the coolant circulation becomes active and some mixing occurs between the main water circulation and the water at the top of the tank. Entry to the top of the tank will therefore not be allowed except under close supervision.

The experimental facilities provided on HERALD comprise four horizontal 6 in. diameter beam tubes, one horizontal 10 in. beam tube, two horizontal 6 in. diameter through tubes and one thermal column with one horizontal 6 in. beam tube, one horizontal 6 in. through tube and one horizontal access hole through the thermal column door with removable 8 in. square graphite stringers. The maximum fluxes available in these tubes at a reactor power of 5MW are expected to be 2×10^{13} thermal neutrons/cm² sec, 10^{13} epithermal neutrons/cm²sec and 10^{8} roentgen/hr gamma flux.

Special equipment associated with the reactor will include two pneumatic self-service rabbit tubes for the delivery of short-lived active samples from the reactor to adjust radiochemical laboratories within a period of 15 sec, a fast neutron chopper which will select neutrons for the determination of total and partial cross sections, and a mobile machine for loading and unloading shielding plugs and experimental equipment in and out of the beam tubes.

Extracted from paper presented at 2nd International Conference on the Peaceful Uses of Atomic Energy

Removal of Plutonium from Body

TWO compounds that grasp metal atoms in octopus-like molecular tentacles have proved effective in flushing out radioactive plutonium from the bodies of laboratory experimental animals—even when treatment is delayed for several days. Scientists of the Argonne National Laboratory Division of Biological and Medical Research, one of a number of research groups studying these compounds, have successfully used this treatment to remove plutonium from the bodies of rats.

Dr. Jack Schubert, a senior chemist at Argonne, recently reported that his laboratory research team has had success with two metal-grasping substances known as DTPA and BAETA which possess "an extraordinary number of tentacles," so arranged that the plutonium atom is imprisoned in a molecular cage from which escape is difficult.

These compounds are known as chelating agents, substances that sequester or trap metal ions to form a stable, water soluble complex that is relatively chemically inert. The complex is naturally flushed out of the body by normal elimination processes. DTPA and BAETA are not poisonous to man.

DTPA (diethylene-triaminepenta-acetic acid) and BAETA (2:2′-bis [di (carboxy-methyl)amino] diethyl ether) are already familiar research tools to the chemist. They belong to a class of specially designed compounds called polyamino acids used for water softening, to remove metal stains from fabrics, to carry trace minerals in agriculture, and to help in the manufacture of synthetic rubber.

Similar findings with DTPA and animals have been reported by Mr. V. H. Smith of the Biology Operation, Hanford Laboratories, Richland, Washington. Use of DTPA to remove cerium (another heavy metal) was reported in 1957 by Dr. Alexander Catsch of the Institute of Radiation Biology at the Reactor Station, Karlsruhe, Germany. The Argonne work is the first reported use of BAETA to remove plutonium.

Several groups of scientists are now studying ways of removing plutonium and other heavy metals from the body. Some substances—notably zirconium citrate and EDTA (ethylenediaminetetraacetic acid)—have proved effective in removing plutonium, providing treatment is delayed no longer than eight hours after exposure.

"Until recently," Dr. Schubert said, "we have had little success in removing appreciable amounts of plutonium which have been retained in tissues for several days."

In a few cases DTPA, as well as zirconium citrate and EDTA, have been given to humans exposed to plutonium, Dr. Schubert reported.

BATTERSEA COLLEGE OF TECHNOLOGY

Regular Output of Engineers For Nuclear Work

LONDON'S "UNOFFICIAL" N-CENTRE

NUCLEAR energy subjects are taught at the Battersea College of Technology, London, as an integral part of the various engineering courses provided. There are no full length specialized nuclear courses and the short courses that are available are limited. Officially the college is not looked upon as a nuclear training centre, yet every year a good proportion of its graduates take up positions with the Atomic Energy Authority and the nuclear power consortia. Also, many of the departments carry out valuable research work for the Authority.

The college is partly aided by the London County Council and because of this is to some extent governed by the council's policy on educational establishments. The council aim at concentrating courses on any specialized subject in one centre and so avoid the duplication of courses in different colleges. As far as they are concerned their nuclear centre is Borough Polytechnic, where a wide range of selection of courses in reactor physics and allied subjects is available (see NUCLEAR ENERGY ENGINEER, November, 1958).

There are of course good grounds for such a policy. Centralization, particularly of courses for which there may be a limited demand, can reduce the waste of valuable teaching power. Concentration of teaching resources and facilities also has distinct academic advantages.

The danger of such a limiting policy, however, is that it tends to overlook the fact that other colleges have to keep abreast of new developments and if carried to extremes it could have the effect of stifling progress. Fortunately, this has not yet happened, but it could well do so.

An engineering college such as Battersea could not possibly ignore the development of nuclear energy and the special needs it has created. Consequently, a formidable array of knowledge and experience in nuclear technology has been built up by the staff and the college has become a thriving nuclear training and research centre.

Degree and Diploma

Nuclear energy in varying aspects is covered by the BSc and Dip Tech courses the college runs in mechanical, chemical electrical, civil, control engineering and in physics, chemistry and metallurgy. The courses leading to a degree, which is a London University internal award, are full-time and last for three years. The courses leading to a Dip Tech are various.

One of the necessary qualifications for the Dip Tech is that the student has worked in industry for some specified time during the course, the period or periods in which he has done this actually being considered an integral part of the course. At which part of the course he does in fact work in industry depends a great deal on how he is financed.

"Thin Sandwich"

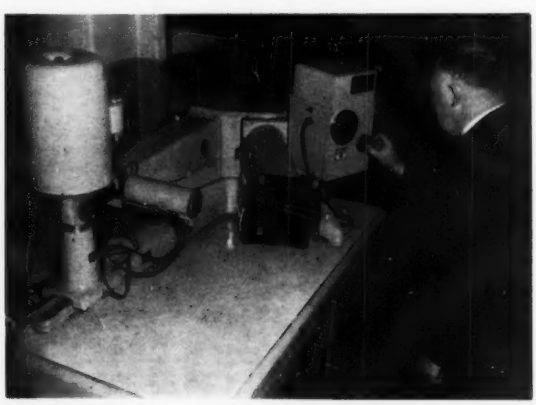
The standard course for the Dip Tech is called a "thin sandwich" course and in this the student spends every alternate six months of the five years it lasts in industry. Usually the students for this type of course are sponsored by industry. The course can be shortened by a year by reducing the third six month period in industry and allowing the student to work at college for a whole academic year.

The different arrangement is the "thick sandwich" course. In this the student spends the first two years as any normal college student and works in industry during his summer vacations. The whole of the third year he spends in industry and returns to college in the fourth year when he takes the finals. Again the students for this type of course are usually industry sponsored.

For L.E.A. Students

A third arrangement is the full-time course, usually taken by students with a Local Education Authority grant. This takes a very similar form to the "thick sandwich," the chief difference being that the student has to find his own jobs during the vacations and the third year when he is industry based. The college usually helps in this situation.

The first two years of the BSc and full-time Dip Tech courses are

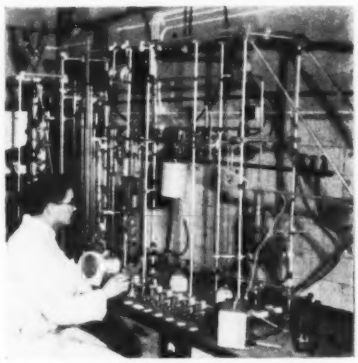


Dr. V. S. Griffiths, Reader in Physical Chemistry, operates the Ramam spectrograph installed at the Battersea College of Technology

usually devoted to fundamentals and it is only in the third year that the more practical knowledge—including that of the nuclear sciences—is introduced. Fundamental nuclear physics, etc., incidentally, are introduced in the early years in what Dr. V. S. Griffiths, Reader in Physical Chemistry, who contributes much to the teaching of nuclear sciences in the college, calls " a subtle way."

Third Year Work

Chemical engineering students learn in their third year about the different types of reactors, materials for their construction, and the desirable properties of moderators and coolants. An attempt is also made

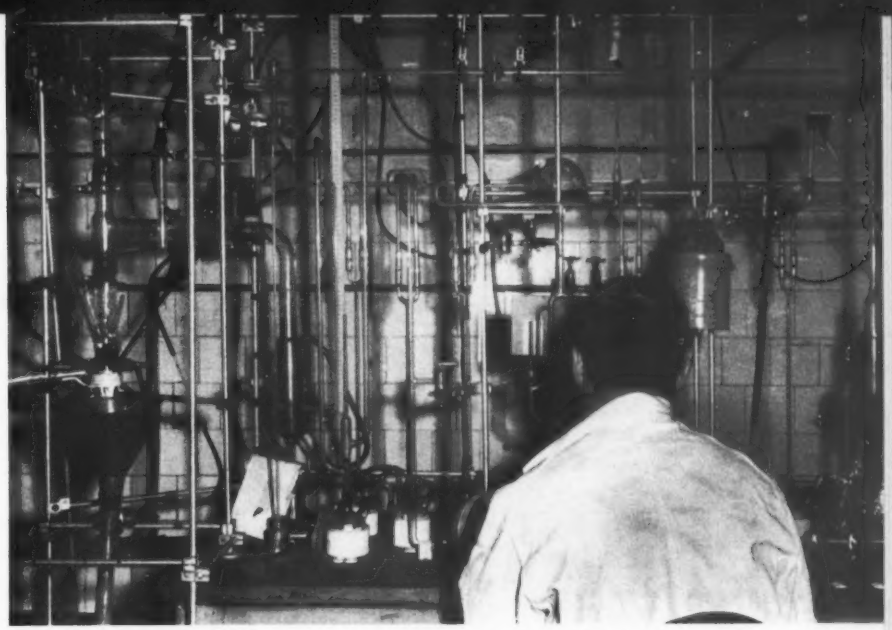


to introduce them to the general economics of nuclear power production and there is practical work with radiochemistry instruments and apparatus.

No Nuclear Engineers Yet

In the metallurgy courses, corrosion properties of materials used in reactor construction and operation are dealt with, while in the control engineering course aspects of nuclear instrumentation are covered. Nuclear energy studies in the other engineering courses follow patterns appropriate to each course.

All of these courses are aimed at producing engineers who could turn to any sort of problem in their own general field—the chemical engineer, for instance, should be able to tackle both petroleum problems as well as those appertaining to nuclear energy, the control engineer should be expert in control and instrumentation whether it is for a nuclear plant, a car factory or heating system. Though many of the successful students take up work in the nuclear field, none of them leave the college as nuclear energy engineers—they are chemical, electrical, civil or control engineers.



Left and above—**A microgas analysis apparatus set up in the metallurgical department of the Battersea College of Technology for research into niobium. The research is being carried out for the Atomic Energy Authority**

The Dip Tech " sandwich " courses take a similar line to the full-time courses, with the addition of lectures on " Industrial Management " (these are also included in the full-time Dip Tech course). These lectures cover such subjects as industrial law, trade unionism, economics, etc. and are aimed at preparing the students for the administrative duties and problems they will encounter when eventually working full-time in industry.

Specifically designed to be of a practical industrial nature, the diploma of technology is more and more being accepted as a high qualification by the professional bodies, industry and others. There are very definitely large numbers of young men and women who are better suited for the Dip Tech courses than, say, for a university course. This has not yet been fully appreciated by parents and young people themselves.

Postgraduate Courses

Beside the BSc and diploma courses, Battersea offers full time post graduate courses in chemical engineering and in control engineering. These lead to the college diploma and this exempts the successful students from the written examinations for associate membership of the appropriate professional institutions.

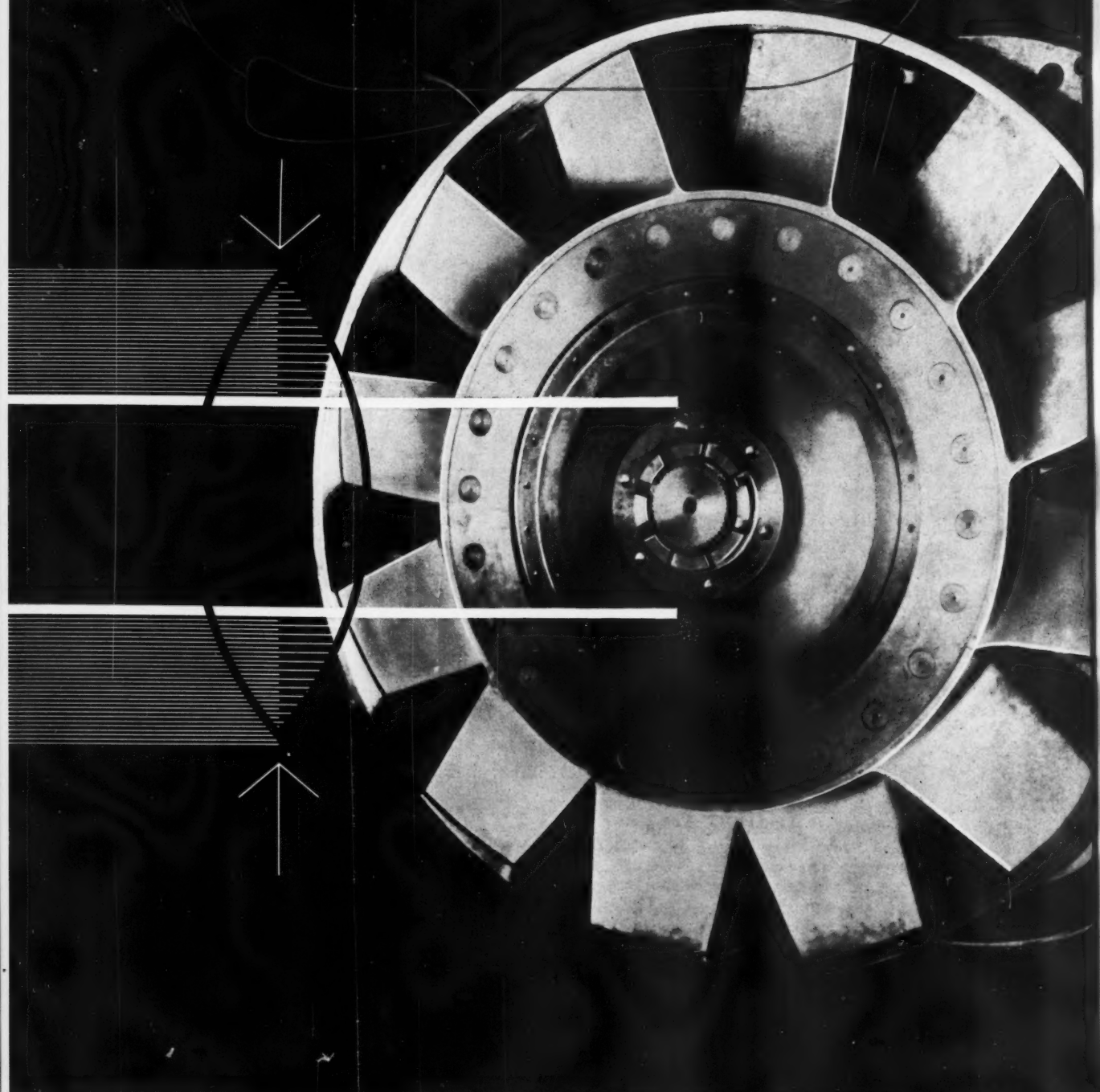
Various short-time and evening courses on applied nuclear subjects are also provided at the college, including lectures on " Industrial Radiation Hazards and Protection," " The Use of Radioactive Isotopes in Metallurgical Research," and " Concrete and Nuclear Radiation Shielding." The first named courses consist of 11 weekly lectures given by members of the college staff and experts from Harwell. The radioisotope lectures last for 12 weeks and are given by a member of the staff of the Royal College of Mines. Another course is a two year evening course on control and instrumentation which covers aspects of nuclear work.

Active Research

The college is very active in the field of research and several of the departments are carrying out work for the Atomic Energy Authority. The work done in the metallurgical and chemistry departments is largely on niobium for the Authority Establishment at Culceth, while the radiography section has been making studies on uranium and graphite for Harwell.

One of the most noticeable features of the Battersea College of Technology is the spirit of co-operation that exists between the different departments. At the same time there is no lessening of the individual pride that is to be found in each department. It is perhaps the combination of these seemingly opposite qualities that makes the college so progressive and alive, and such an admirable background for the nuclear age engineer and technician.

APL blower oil or



or sentry-go at Bradwell...

The crucial points of the high pressure CO_2 coolant circuit at Bradwell will be the blower shaft seals. Every minute of every working day Shell APL blower oil will guard these escape points—being continually pumped into the seals and bearings, led away, purified and recirculated.

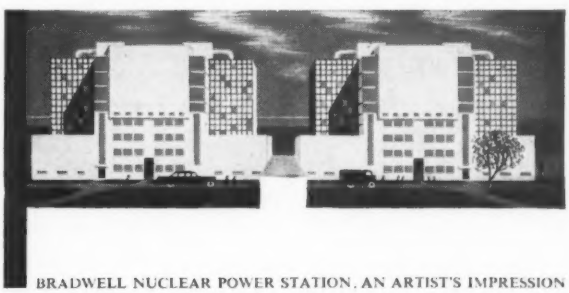
This very remarkable oil presents a two-way seal. Outwards, there is a minimum CO_2 loss as the oil has the lowest possible gas solubility. Inwards, in spite of the heat of the gas, oil vapour contamination is negligible thanks to the extremely low vapour pressure of the oil.

The research that went into APL blower oil is characteristic of the way Shell set about doing things. It was conducted at Shell's Research Centre at Thornton in close collaboration with the U.K. A.E.A. and the blower manufacturers. In the course of much fundamental research, a wide range of oils was subjected to vapour pressure and gas solubility tests in the laboratory. Selected oils from this range were used in the bearings and seals of a blower rig. In 1956, after four years of research, the finished product joined the Shell Atomic Power Lubricants range—marketed under the name of Shell APL 729. This oil has been in use at Calder Hall since the autumn of 1956.

The moral of the story is that Shell research is supremely applicational. The Centre at Thornton is always ready to work with even the most specialised sectors of industry to produce the right oil for the job. If you and your organisation have any major lubrication problem it pays to get in touch with your local distributor of Shell Industrial Lubricants.

The Research Story

Though the sealing action demanded of Shell blower oil is common in other industrial equipment such as hydrogen-cooled alternators, there were quite a few additional problems. It was necessary for the oil to have long life, low vapour pressure, low gas solubility, good thermal stability and high film strength —to be able to withstand high temperatures and to be resistant to all kinds of corrosive influences, including carbonic acid. The crux of the research was to combine all the above requirements into one oil, in order to minimise back diffusion of molecules which would contaminate the reactor.



BRADWELL NUCLEAR POWER STATION. AN ARTIST'S IMPRESSION

SHELL

ATOMIC POWER LUBRICANTS

another proof of Shell leadership in lubrication

Progress at Berkeley

PROJECT NOW IN THIRD YEAR

No. 1 reactor at Berkeley with the boilers in position

FOLLOWING the progress of a nuclear power station under construction can be as interesting and stimulating as watching the development of a growing child. Stages are reached which appear to the intermittent onlooker as being leaps ahead of anything he had previously seen or imagined and which sometimes provide him with a definite and often exciting hint as to what will finally emerge.

It is hard to believe that the site of the Berkeley nuclear power station, which the AEI-John Thompson Nuclear Energy Co. is building for the Central Electricity Generating Board on the banks of the River Severn, was just over two years ago a quiet 100-acre farm. Equally impressive is the transformation that has occurred over the past 12 months.

A year ago the visitor to the site was confronted with a sea of mud out of which he could just distinguish the foundations of the principal buildings and a mass of gin poles and cranes and boiler and pressure vessel parts. To-day the mud is still there but instead of having to look down the visitor now has to look upwards. The 100 ft building which houses the No. 1 reactor with its eight boilers placed round it like the tentacles of a rather squat octopus makes an impressive sight.

Insulating the PV and Boilers

Thermal insulation at Berkeley is being carried out by the Cape Asbestos Co., Ltd., with " Caposite " amosite asbestos moulded blocks and pipe sections, and " Rocksil " rock wool. The picture on the left shows lagging on the lower dome of No. 1 reactor pressure vessel. This lagging will eventually be covered with aluminium. In the picture below a workman is fitting lagging to one of the boilers before the boiler is stress relieved

When the station is completed each boiler will be housed in its own glass-walled structure, a novel and attractive feature of the design. Some of these structures have already been erected, so giving the visitor a good idea as to what the station will finally look like. A further glimpse into the future is provided by the blue glass panels that already adorn the sides of the reactor building.

Cleaning in Progress

During a recent visit to the site by NUCLEAR ENERGY ENGINEER, preparations were in hand for the stress relieving of the pressure vessel for reactor No. 1 and a start had been made to the cleaning and tubing of the boilers. The latter work is undertaken from specially designed air

A charge tube boss being lowered into position for welding on the top dome of the No. 1 reactor pressure vessel. There are 193 charge tube and control rod bosses in the dome

conditioned cleaning rooms erected on top of the boilers. Nobody can enter the boilers without first passing through these rooms and changing into a special set of protective clothing. The object is to ensure that nothing incompatible with steel gets inside the boilers.

No. 2 Three Months Behind

Work on reactor No. 2 is about three months behind that on the first reactor. The diagrid was recently lowered into position and the pressure vessel was expected to be sealed shortly afterwards. The first of the eight boilers was also shortly due to be erected.

Lying parallel to the axis of the two reactor buildings is the low graceful turbine hall, which is complete and weatherproofed. The painters and decorators have been busy on the inside for some time, and installation of equipment has started.

Overspaced?

Compared with the layouts of other nuclear power stations currently being built in Britain, the distances between the two reactors and turbine hall are large, too large in the view of some experts. The contractors, however, are confident that by spreading out a little they have been able to lower costs of the civil engineering work involved without it impairing ultimate station operating expenses.

At the other stations compactness of layout is being facilitated by the use of Goliath cranes for the lifting of the heavy engineering parts. At Berkeley such work is carried out by gin poles and derrick cranes.

Slightly baffling at first is the positioning of the transformer equipment which will feed the station's output into the grid. It is situated on the far side of the reactors away from the turbine hall. Reason for this remoteness is that anywhere else it would get in the way of the view from nearby ancient Berkeley Castle.

Preparations are made for the welding of a tube header to a low-pressure steam evaporator on one of the boilers attached to the No. 1 reactor at Berkeley. The evaporator, seen at left, was made by the John Thompson Water Tube Boilers Co.

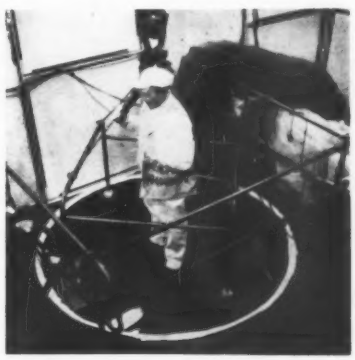
On a nuclear station it is only natural that the visitor should turn his attention primarily to the nuclear side of it, although the other, more conventional, aspects of it are just as impressive. Of the two cofferdams that make up the cooling water inlet, one is finished and among the engineers and workmen is known affectionately as the "cathedral," its high vaulted ceiling inside giving it an appropriately ethereal atmosphere. The inlet is sited some way off the river bank so as to be able to take in water during low tide. Access to the intake, which is at present made by means of a temporary Bailey bridge, will be by a special access tunnel.

A little upstream from the intake is the outfall. A special baffle wall is being built to prevent warm water from this mixing with water entering the intake.

Completion of the station for operation is due in 1960. Initial electrical output will be 275 MW.

Contractors

Principal contractors on the Berkeley project are John Laing, Ltd., who are responsible for civil engineering work on the reactors; Balfour Beatty, Ltd., responsible for civil engineering work on the turbine hall, workshops, administration buildings and condensing water system; AEI, Ltd., who through their Turbine Generator and Heavy Plant Divisions, are supplying the turbine house equipment, two dumped steam condensers, steam jet air ejectors, water/water heat exchangers, oil coolers, generator hydrogen cooler units, and 16 gas circulators and gas duct bellows units; British Thomson-Houston, Ltd., who are supplying the control rod actuators and nearly 1,000 auxiliary motors; and John Thompson, Ltd., who are responsible for constructing the pressure vessels and boilers.



Before the boilers are sealed for operational use they have to be thoroughly cleaned. Men carrying out the cleaning operations wear special protective clothing and their only means of access to the boilers is through a special "clean" room which is temporarily erected at the top of each boiler, some 70 ft above ground level. The rooms are dry-air conditioned and no materials incompatible with steel are allowed into them

Concrete for BIOLOGICAL SHIELDING

by A. L. BRAKE, A.M.I.Struct.E.

Based on a lecture the author recently delivered at the South East London Technical College, this article deals with the different types of concrete mix available for use in the biological shields built round nuclear reactors and the construction problems involved. Special reference is made to the Berkeley nuclear power station project

THE purpose of the main biological shielding of a nuclear reactor is to protect operatives from the neutrons that leak from the reactor core and from the gamma rays that are produced with decay of fission products. The extent of protection which the shielding should afford is governed by the maximum levels of radiation to which operatives can be exposed without impairing their health, the levels being laid down by the International Commission on Radiological Protection and the Medical Council.

On most counts concrete is an excellent material for use as biological shielding. Being dense, it gives adequate protection against gamma rays and because it contains hydrogen, in the form of chemically combined water of hydration, acts as a suitable medium for slowing down and capturing neutrons. It is economical to produce and it is a first-class structural material.

Because of this last quality concrete biological shielding plays a dual role. Not only does it provide protection against radiation but also it forms the main structural element of the reactor building. The top face acts as the charging face and the side walls give support to the floors which house the instrumentation and other ancillary equipment.

A disadvantage of concrete as a shielding material is its low conductivity.

Other Guiding Factors

There are of course other materials suitable for use as biological shielding and the final choice rests on factors other than physico-biological considerations. This is particularly true in the case of reactors for commercial power stations. The shielding necessary for the gas-cooled graphite reactors that will be used in the nuclear stations being currently built in Britain are massive structures—up to 100 ft high and 60 ft in diameter. To achieve the nuclear power station programme these shields must be constructed at a very rapid rate and therefore the construction materials must be readily available in large quantities and be capable of being stored on site without deterioration.

In selecting a material for economic reasons its evaluation should not be based merely on one point of view, but from consideration of the cost of the reactor as a whole.

Materials that make suitable biological shields are water, concrete and combinations of these, either singly or together, with iron, steel, lead, etc.

Now concrete can be made with various aggregates and according to these aggregates so the density of the concrete varies. Using a heavy normal aggregate of limestone, for instance, it is possible to produce a concrete with an immediate wet density of about 150 lb/cu.ft. With barytes, which is a naturally occurring form of barium sulphate, a concrete with an immediate wet density of 227 lb/cu.ft is possible. The density can be further increased, to 250 lb/cu.ft, by using high grade iron ore, such as magnetite, grade C (from Kiruna, Sweden). By using iron shot, an even higher density of 350 lb/cu.ft is possible.

Various other dense materials have been considered for use in biological shields, but after investigations many of them have been found unsuitable.

Essential Properties

Whatever aggregate is chosen for a biological shielding it must have met the following requirements:—

(1) The chemical and physical properties must have the approval of the "shielding expert" and these properties must remain constant throughout the construction.

(2) The concrete produced with the chosen aggregate must meet the structural requirements and also remain stable throughout the temperature range to which it will be

MR. A. L. BRAKE, AMIStructE, who is the civil engineering project engineer for the Berkeley nuclear power station, has been concerned with this aspect of nuclear energy from early days. From 1947 to 1951 he was assistant structural engineer in the Ministry of Works department of atomic energy at Risley and during that time was engaged on the design of the Windscale works. After leaving Risley, Mr. Brake was for four years resident site structural engineer at the Atomic Weapons Research Establishment, Aldermaston. In 1955 he joined W. S. Atkins and Partners, the Consulting Engineers, and took up his present duties on the Berkeley project under the direction of Mr. D. R. R. Dick, partner in the firm and chief engineer of their nuclear department. Mr. Dick was also Mr. Brake's chief on the Windscale project.

Concreting the biological shield for one of the reactors at Berkeley

subjected during the operation of the reactor.

(3) The concrete produced with the chosen aggregate must have good workability and be capable of being properly compacted and finished.

(4) The source of the aggregate must be at all times adequate to meet the demand.

Limestone as Aggregate

In the Berkeley shielding design studies no justification was found for using any aggregate other than the local limestone except in one or two particular locations where lack of space necessitated a shield thinner than could be obtained with this aggregate.

The factors influencing this decision to use limestone were many and complex and will not always necessarily apply. Reactor plant layout is tending to become more compact and the space available for shielding is shrinking. Concrete with greater densities will have to be used. When there is sufficient demand in Britain for large quantities of heavy aggregate for shielding it will no doubt become available at competitive prices.

This stage has already been reached in Canada and the United States where Canadian mined ilmenite (which contains titanium and is therefore unsuitable for steel production) is used to produce a concrete having an immediate wet density of about 250 lb/cu.ft. This is used extensively for biological shields reducing both overall cost and space requirement for complete plant. At the present time only samples of ilmenite aggregate are available in this country. If it could be imported in large quantities and delivered to site crushed and graded for something under £10 a ton it could prove a serious competitor to normal aggregates.

Good but Costly

Magnetite Cs, the high grade iron ore which is imported into this country from Kiruna, Sweden, for steel manufacture is an expensive proposition. It costs about £8 per ton as unloaded in bulk and the cost of duty, transport and crushing just about doubles this figure by the time it arrives on site.

Crushing is costly, for being a hard material it damages normal crushing plant and the special crushers used in Canada and the U.S. are not yet available over here.

Magnetite C makes a good structural concrete giving 28 day crushing strengths of about 7,000 lb/sq.in. for an 8:1 mix with a W/C ratio of 0.44. The thermal conductivity of magnetite concrete to this mix is 10.3 B.t.u./°F./in/ft²/hr, which is higher than that for normal concrete.

Magnetite concrete is acceptable as a shielding material but is not so efficient as barytes concrete in spite of the fact that it has a greater density. Thus a 6 ft 6 in. thickness of magnetite concrete would be required to replace a 6 ft thickness of barytes concrete.

Magnetite grade "D"—a lower grade ore which is reputed to contain a percentage of limestone is cheaper than the grade "C". This is probably the basis for the magnetite concrete being used in the shielding at Hunterston. The immediate wet density of concrete made with this aggregate is probably in the region of 200 lb/cu.ft.

Barytes has been used quite often in this country to make shielding concrete—mostly for research equipment where often space considerations are of prime importance. It is mined both in this country and abroad and its characteristics vary considerably as between the various sources.

Barytes for use in shielding concrete should:—

(*a*) Have a specific gravity of about 4.2.

(*b*) Remain stable at temperatures up to about 250°C.

(*c*) Be capable of being transported and stored without serious deterioration.

Varies Considerably

Many sources of barytes fall down in one or more of these respects.

Barytes concrete made with aggregates as described above to an 8:1 mix with a W/C ratio of 0.5 gives a crushing strength at 28 days of about 6,000 lb/sq.in. Prices of barytes aggregates vary from about £14 to £20 a ton. Very roughly it can be stated that a biological shield of barytes concrete need be only about two thirds the thickness of one made with normal concrete.

Before deciding to use barytes concrete in locations where nuclear radiation will cause a big temperature rise, laboratory tests should be carried out to ensure that the concrete made with the chosen aggregate is suitable for the purpose. It has been found that concrete made with certain barytes becomes unstable at temperatures not much above 100°C.

Concrete batching plant at the Berkeley nuclear power station site. Aggregate storage bins are in the foreground

Iron shot concrete is normally only used where plant requirements call for a very high density concrete in particular locations. A very close check has to be kept on the shot to ensure that it is up to specification and furthermore it is a material which deteriorates rapidly unless stored under ideal conditions.

Concrete made with iron shot is difficult to mix, compact and finish off. Iron shot concrete of 8 : 1 mix with a W/C ratio of 0.3 gives crushing strengths at 28 days of about 10,000 lb/sq.in. and thermal conductivity of 13.7 B.t.u's/°F./in./ft²/hr. Iron shot costs about £30 per ton.

At Berkeley the coarse aggregate used in the main biological shield is carboniferous limestone which is available in quantity from local quarries. The fine aggregate is ball mill sand and the cement—ordinary Portland.

Data Required

In the preliminary design stage the "shielding" designer requires to know:—

(1) The chemical analysis of all these materials.

(2) The probable mix proportions and W/C ratio together with the proportion of the water which will be chemically combined (i.e. water of hydration).

(3) The percentage of reinforcing steel.

(4) The maximum permissible peak temperature which the concrete designer can tolerate in the shield

(5) An assessment of the probable dry density of the shield during the period of the operation of the reactor.

Armed with this data, the shielding designer can calculate the thickness of shielding concrete required to limit the radiation outside the shield to the safe dose level stipulated. He can also calculate the thickness of steel thermal shield required and the air cooling necessary to keep the peak temperature in the shield below the maximum permissible laid down by the concrete designer.

The concrete designer has to take account of various factors in arriving at this figure.

(1) The tensile and compressive stresses set up in the shield due to the temperature gradient across it.

(2) The fact that most normal aggregates continue to expand up to about 1,000°F. whereas the cement itself stops expanding at about 500°F. and begins to shrink.

(3) The chemical changes which begin to take place at about 800°F. due to loss of water of hydration.

In a normal reinforced concrete shield of about 10 ft thickness it will be found that item (1) is the limiting factor and that a permissible peak in excess of 200°F. will give an answer which involves the use of an unacceptable percentage of reinforcing steel to resist the tensile stresses. At Berkeley the main biological shield side walls are about 9 ft thick. The outer face contains approximately 1 per cent. of reinforcing steel and the inner face contains 0.5 per cent. of reinforcing steel. A minimum percentage is of course required to control shrinkage.

Steel Shielding

The walls of the shield are protected by a total of 4 in. of steel thermal shielding made up of the 3 in. pressure vessel shell and the No. 2—$\frac{1}{2}$ in. plates—of the "gasholder." The top cap of the biological shield and the foundation raft, which are at opposite ends of the fuel channels and therefore exposed to neutron "streaming," are protected by the pressure vessel top and bottom domes plus an additional 5 in. of steel thermal shielding to limit heat generation.

The Berkeley shield is a cylinder closed at the top by the biological shield cap and fixed at the base to secondary shielding and foundation raft. The barrel is unrestrained.

The maximum peak temperature will occur in a ring of the barrel opposite the centre of the core and will be less than 200°F.

The mix used in the Berkeley side shield is 3.91 : 2.59 : 1 using $\frac{3}{4}$ in. limestone coarse aggregate with a W/C ratio of 0.6. The immediate wet density is about 150 lb/cu.ft and the ultimate dry density based on the oven drying tests specified by the CEGB is of the order of 142 lb/cu.ft. This latter figure is the one which the shielding designer must use in his calculations.

Special Needs Met

Barytes concrete will be used only for pre-cast shielding blocks to be placed in certain locations in the secondary shielding, where access is required for plant installation at a late stage in the construction programme and where limitations on space do not allow normal concrete blocks to be used. Iron shot concrete will be used in one thin layer in the top cap in a particular location where a very high density is required.

In order to minimize the effects of shrinkage—complete rings of the Berkeley biological shield were cast in one operation. They were cast in lifts of approximately 3 ft and each lift required between 200 and 250 cu.yd of concrete.

This was provided by John Laing's central batching plant located south of the two reactors. The plant comprises a central batching and mixing unit with conveyor belt feed

and two 2 cu.yd mixers. These feed four concrete pumps. Total output of the plant is about 80 cu.yd/hr.

Balfour Beatty, the other civil engineering firm working on the power station, operate a similar batching plant elsewhere on the site.

Concrete is Piped

For constructing the lift of the biological shield concrete was pumped via two pairs of pipes to two positions on opposite sides of the ring and from these parts was spread in opposite directions round the ring. This procedure was necessary because the concrete pumps deliver 20 yd/hr and if concrete were to be fed into one position in the shutters at this rate it would not be possible to spread and compact it properly.

All the concrete placed was carefully compacted by means of immersion vibrators. This process must be strictly controlled since either under or over vibration will result in variation in density throughout the lift. Too little vibration can result in voids. Too much vibration can result in the " fines " being brought to the surface.

Great care must also be taken in working the concrete around the various penetrations for gas ducting, etc.

All the concrete used on the Berkeley nuclear power station is strictly controlled from the site concrete laboratory under the direction of the AEI-JT resident engineer. All incoming materials such as aggregates and cement are regularly tested to ensure that they conform to British Standard Specification and do not vary appreciably.

The Test

Samples of concrete are taken from the points of placing and they are first tested for workability by means of the automatic compacting factor apparatus which is incorporated in the main batching plant of both the main civil contractors. The samples are then used to make 6 in. test cubes. A sample from each source and for each grade of concrete is taken at least once per day or for each 200 yd of the particular grade placed.

Twenty-four hours after they have been made the cubes are weighed in air and in water in the laboratory to determine their immediate wet density. They are then placed in water curing tanks, the water being maintained at 60°F. Two cubes from each sample are tested at 7 days and three cubes from each sample are tested at 28 days in a Dennison Compression machine.

For the main biological shield concrete it was specified that:—

(1) The maximum permissible compacting factor should be 0.92.

(2) The minimum crushing strength at 28 days should be 3,000 lb/sq.in.

(3) The immediate wet density should be not less than 150 lb/cu.ft.

In addition to these tests the CEGB required additional samples to be taken from each lift of the shield and subjected to oven drying tests for the purpose of assessing the probable dry density in any part of the shield.

Each lift of the main biological shield was divided into a number of approximately equal segments and whilst concreting was in progress samples of the concrete were taken from each segment of each lift. From the sample from each segment three 6 in. cubes were made on the working scaffold, vibration being carried out by "Kango" hammer until thorough compaction has been achieved. When the initial set had taken place the cubes were removed to the concrete laboratory. The immediate wet density for a lift was obtained by weighing all the cubes in air and water 24 hr after casting.

Six cubes were then selected at random from the total cubes for each lift. These were cured in water for 7 days and again weighed in air and water. The density thus obtained is " The 7 day wet density." These six cubes from each lift were then dried in a ventilated oven at 105°C. (±5°C.) until two successive weighings not less than 24 hr apart gave equal results.

The " dry density " was derived from the weights thus obtained and from the volumes obtained during the " immediate wet density " test. The drying losses at Berkeley average about 8 lb/cu.ft, giving a dry density of about 142 lb/cu.ft.

This test probably gives a pessimistic figure for dry density since it is doubtful whether a 9 ft thick shield will ever dry out to the same extent as a 6 in. cube dried in an oven. The dry density of the Berkeley shield during operation is likely to be around 145 lb/cu.ft.

Acknowledgements

Acknowledgements are made to the chief project engineer of the Central Electricity Generating Board, the chief engineer of AEI-John Thompson Nuclear Energy Co., Ltd., the principal of the South East London Technical College and to the Consulting Engineers, W. S. Atkins and Partners, for permission to publish this article. Photographs are supplied by John Laing and Sons Ltd.

Sample cube of concrete for biological shielding undergoing test in the concrete laboratory

Drums of uranium concentrate in the store at Springfields awaiting sampling and costing

SPRINGFIELDS

NEW PROCESS PLANT INCORPORATING NEW PROCESSES AND TECHNIQUES HAS RECENTLY BEEN INSTALLED TO PUT PRODUCTION ON A MORE EFFICIENT FOOTING AND TO ENABLE THE FACTORY TO MEET THE DEMANDS OF THE PLANNED CEGB NUCLEAR POWER STATIONS AND OTHERS

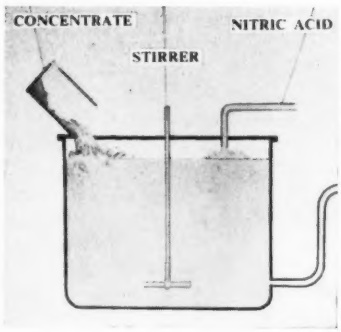
WHEN the new uranium processing plant at the United Kingdom Atomic Energy Authority's factory at Springfields, Lancs., is completed, some time in 1960, the factory will compare with the most up-to-date and efficient mass production unit of any other industry. Already much of the plant is installed and in use and some of the old process methods and equipment discarded. An entirely new fuel element assembly line, which is said to be about three times as speedy as the old one, is also in operation.

The factory produces fuel elements for the Calder Hall and Chapelcross power stations and for BEPO and at Harwell. Fuel elements for the planned CEGB and SSEB nuclear stations and for those to be built overseas will also be made there.

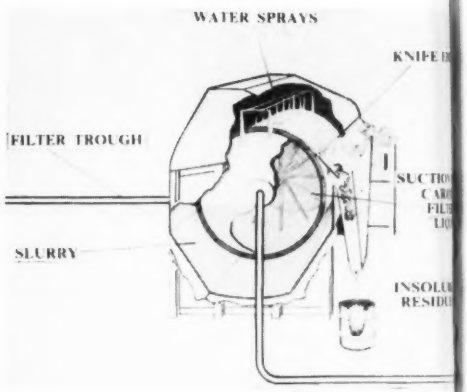
Also handled at Springfields is the uranium extracted from irradiated fuel elements at Windscale. It arrives at the factory in the form of a uranyl nitrate solution. This is converted into uranium hexaflouride, which is sent to Capenhurst for re-enrichment in the diffusion plant there.

For security reasons no detailed figures for fuel element production are published—they would make the calculation of Britain's plutonium stockpile too easy. The authority has revealed, however, that during the ten years the factory has been used for processing uranium—mustard gas was manufactured there before—the output of fuel elements of various types has reached the millionth mark.

A million could certainly be reached in far less time than ten

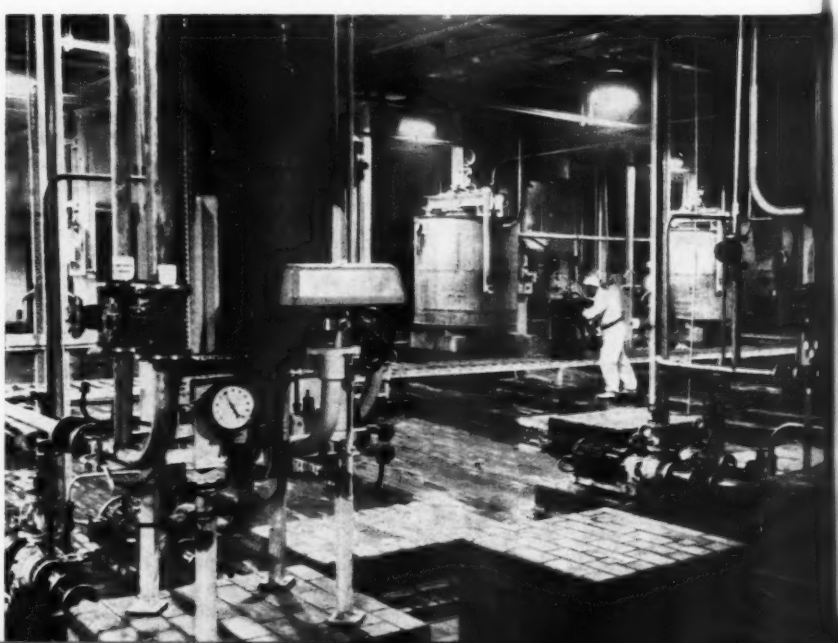


1 Uranium is delivered to Springfields in the form of "concentrate"—crude uranium oxide from which mined impurities have been removed. As required the concentrate is tipped into tanks fitted with stirrers and heating coils where it is dissolved in nitric acid. The resulting solution, after cooling, is then fed into rotary filters

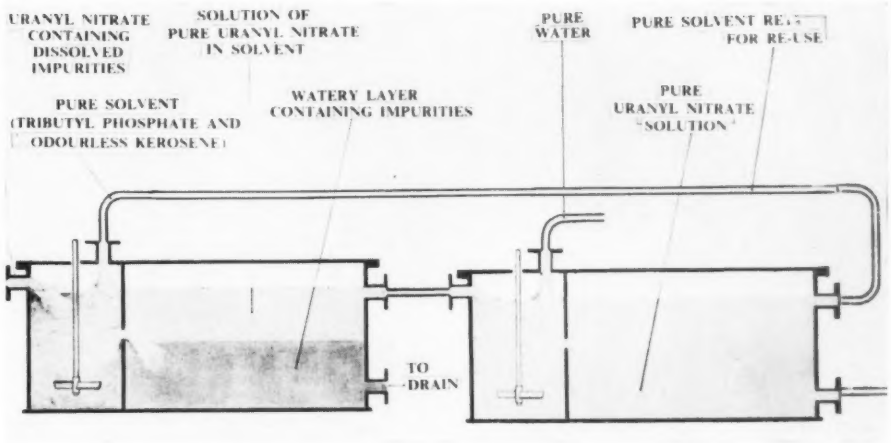


2 The filters consist of horizontal drums of fine mesh with a vacuum applied to the inside. As they rotate through the slurry from the dissolvers the uranyl nitrate solution is sucked through the mesh leaving insoluble impurities on the outside

Underneath the deck carrying the primary dissolvers and filters, where various intermediate stages are performed



UKAEA URANIUM FUEL FACTORY


URANYL NITRATE CONTAINING DISSOLVED IMPURITIES
SOLUTION OF PURE URANYL NITRATE IN SOLVENT
PURE WATER
PURE SOLVENT RE
FOR RE-USE
PURE SOLVENT (TRIBUTYL PHOSPHATE AND ODOURLESS KEROSENE)
WATERY LAYER CONTAINING IMPURITIES
PURE URANYL NITRATE SOLUTION
TO DRAIN

3 The uranium solution from the rotary filters is purified by solvent extraction in mixer settler units arranged in cascade. Uranyl nitrate collects in the solvent—a solution of tributyl phosphate in odourless kerosene—leaving impurities in the aqueous phase. From the settler sections of each unit the solvent flows "up" to the mixer of the next section, whilst the aqueous phase flows "down" to the previous one. At the top of the plant the nitrate is washed out of the solvent by weak nitric acid, not pure water, as indicated above

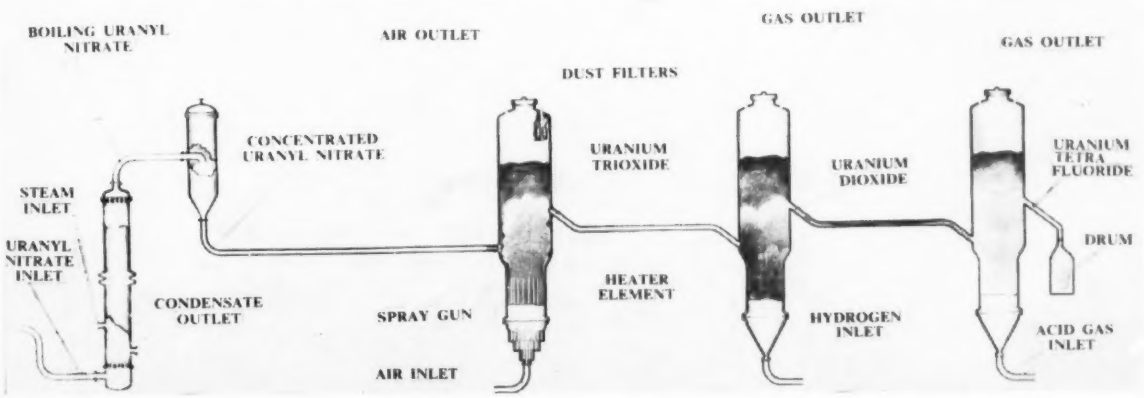
years with the new plant, and in even less if the number of fuel element assembly lines was increased. The original plant, which is scattered throughout separate buildings, was, of course, of necessity of an experimental nature and the continuous production unit could be designed only after detailed investigation and consideration of the various operations involved in each processing stage.

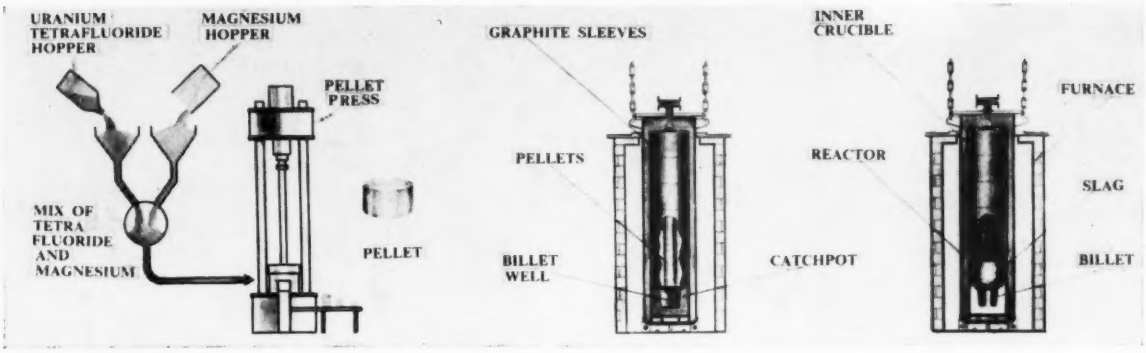
Some of the stages have been eliminated from the new plant or will be eliminated when it is in full operation. For instance the original plant was designed to start off with uranium ore—the new plant starts off with concentrate.

The ore had to be crushed and then converted into a slurry in a ball mill. The slurry was then treated with nitric and sulphuric acids which dissolved the uranium and left the bulk of impurities in suspension. Uranium was precipitated from the crude uranyl nitrate solution by the addition of hydrogen peroxide, the precipitate, uranium peroxide, being collected on filter presses. The filter cake was then dissolved in nitric acid and the resulting solution of

Uranyl nitrate storage tanks

4 In the present installation at Springfields the uranyl nitrate solution is treated with ammonia to precipitate the uranium diuranate which is then put through a Dryway plant to produce ammonium tetrafluoride. Ultimately this process will be carried out by fluidized bed methods, which eliminate the ammonium diuranate stage. The uranyl nitrate solution will be evaporated to a thick syrupy concentrate. This will be converted to uranium trioxide, which will then be reduced by hydrogen to uranium dioxide, which in its turn will react with anhydrous hydrofluoric acid to produce uranium tetrafluoride. Plant for the fluidized beds is now under construction and is expected to be completed by 1960





5 **The uranium tetrafluoride is mixed with magnesium turnings and the combination pressed into pellets. These are heated in a furnace reactor which contains sectionalized graphite linings. Reduction takes place and a billet of uranium and a slag are produced**

uranyl nitrate purified by an ether process.

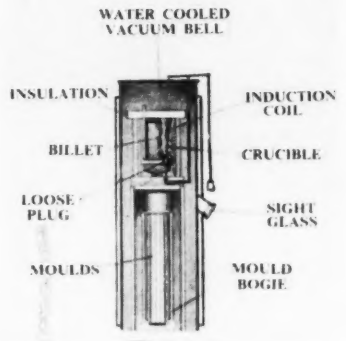
The new plant eliminates the peroxide stage and the use of ether. After being checked for quality, the uranium concentrate is dissolved in nitricacid**(1)**and the resultant solution passed through rotary filters **(2)**. Purification of the uranyl nitrate is then carried out by a solvent extraction process **(3)**, the solvent being tributyl phosphate in odourless kerosene.

From here the processing reverts to the original, although ultimately this will also be replaced. The purified uranyl nitrate is treated with ammonia to produce ammonium diuranate. This is heated until converted into a uranium trioxide, which is then treated with hydrogen to produce the dioxide which in turn is reacted with anhydrous hydrofluoric acid to give uranium tetrafluoride. The conversion of the ammonium diuranate into the tetrafluoride takes place in what is called a Dryway furnace. Eventually the diuranate stage will be left out and the uranyl nitrate converted to uranium tetrafluoride, still in three stages, by fluidized bed methods **(4)**. The section of the new plant in which this will be done is now under construction.

The next stage is the reduction of the uranium tetrafluoride with magnesium **(5)**. At one time this was carried out with calcium and considerable development work had to be done before the cheaper magnesium could be used. The product of the reduction is a billet of uranium metal, weighing in the region of 200 kg.

Casting of the billet into rods takes place in electric vacuum furnaces **(6)**, of which there are eight in the new plant. From the furnace the rods pass to a store where they are kept until required for heat treatment and machining **(7)**.

The new fuel element assembly line **(8)**, where the rods are inserted and sealed into finned cans, and tested, ready for use in a reactor, incorporates many new features. Pressurization of the cans to ensure perfect contact between the inside of the cans and the rods, for instance, is carried out by oil instead of gas,

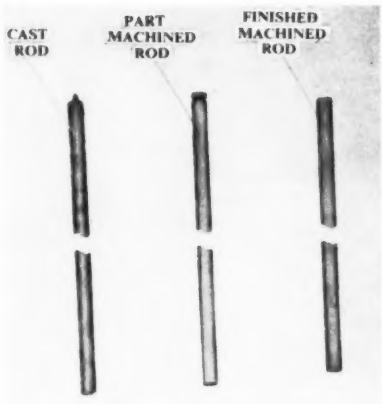


6 **The billet of uranium is placed in a graphite crucible and melted under vacuum in a high frequency electric furnace. The molten uranium is then run into a nest of moulds**

(Right) *Nest of moulds for uranium fuel rods being placed into a vacuum casting furnace*

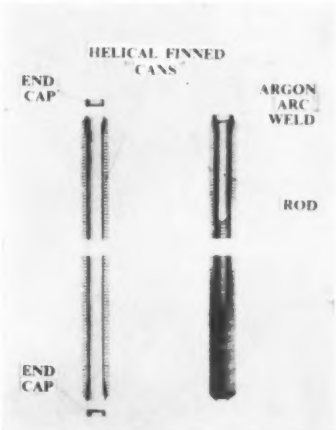
In this room cast rods of uranium are stored as they are received from the vacuum casting line before proceeding to the machining line

(Left) *Beta quench apparatus. An uranium rod being removed after receiving heat treatment designed to reduce grain size of the meal.* (Above) *Alpha annealing apparatus. Further heat treatment is applied for reducing the grain size*



7 The cast rods undergo a succession of machining operations to bring them to the desired design requirements and heat treatments designed to reduce the grain size of the uranium. The latter is aimed at minimizing distortion of the rods under irradiation. The machining operations are entirely conventional and are carried out on standard lathes and centreless turners. The only special precautions taken are the provision of an exhaust system and a copious supply of coolant to prevent ignition of the uranium swarf and to minimize the risk of particles escaping to the atmosphere. The turnings are collected, cleaned and added to subsequent casting charges. The rods are inspected, checked for dimensional accuracy, individually numbered and then sent for assembly into fuel elements. Early fuel elements, for Bepo and the Windscale reactors, used aluminium as the canning material, now, Magnox is used

as in the old plant. New is the ultrasonic equipment for cleaning the fins of the cans. Most impressive change, however, is the conveyor belt system which enables all operations and tests to be carried out with the maximum of efficiency. Additional fuel assembly lines will be brought into operation when the demand for fuel elements increases. and indeed a second line has already been planned for meeting the requirements of the first CEGB nuclear power stations. The processing plant incidentally is designed to serve up to five lines.



8 The fuel element cans are open-ended tubes. A cup is welded into the end of each can and an uranium rod inserted. The second end cup is welded into position and the can pressurized to ensure good heat transfer from rod to can. Various tests follow, the can is cleaned, for the second time, end pieces and braces are attached and the fuel element, ready for use in a reactor, is packed for despatch. All these processes are now carried out on a straight continuous production line

CONCRETE PRESSURE VESSELS

Part II

Part I of this article, which appeared in last month's issue, dealt with the practical side of the design and construction of the pressure vessels for the G2 and G3 reactors at the French Atomic Energy Commission Establishment, Marcoule. This month, the authors discuss some of the theoretical aspects

by J. Bellier and M. Tourasse

THE pressure vessels for the G2 and G3 reactors at Marcoule and the prestressing cables used had to be designed and constructed according to the various forces involved. The most important of these, in order of size, are:—

1. The bursting forces due to the internal pressure and forces opposed to prestressing;
2. The weight of the cylinders and cupolas; and
3. The localized forces from the lateral wedging jacks and at the end of the graphite pile.

No practical account need be taken of the weight of the pile and its supporting framework in view of the strength of the base which carries them.

Finally, but only as a reminder, because the problem is too complex to be dealt with here, the thermal forces should be mentioned.

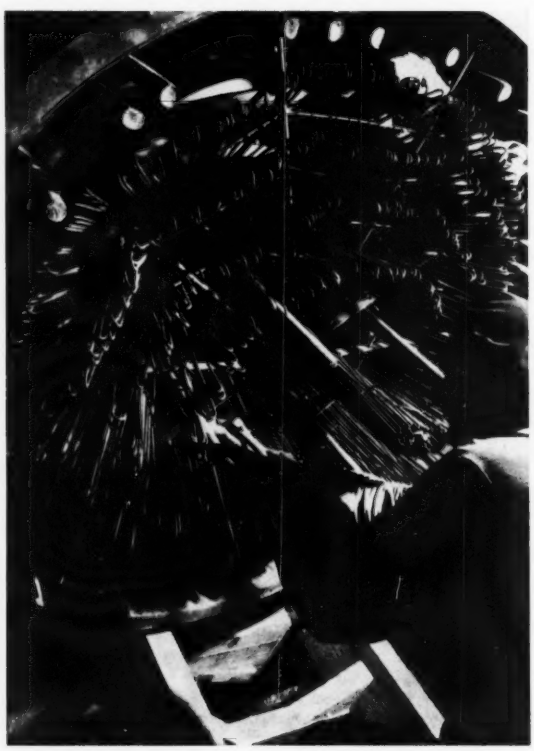
Simple at First

The elasticity calculation of the pressure vessels under the heavy strains (pressure, prestressing) is very simple as a first approximation, but becomes complicated when the exact shapes, hyperstatic effects and actual working conditions are taken into account.

The latter do not, however, greatly change the results, and the basic calculations described in what follows illustrate the essential points.

For the cylindrical body, the first approximation consists in considering the construction as a thick tube perfectly equilibrated about its axis and of undefined length, bound by continuous hoops without friction. The elasticity formulae then give the stresses in the concrete due to the pressure; these are tensile stresses and the maximum acts at the internal fibre tangentially. In the same way, the stresses due to the hoops as a function of their tension, in particular the tangential stress on the internal fibre, are obtained.

Comparison between the two at once gives the hoop tension necessary to counteract the maximum effect of the pressure. Thus, for a pressure of 426.7 lb/sq.in. (test pressure), a hoop tension of 2,250 tons per running metre of cylinder is required. In practice, of course, it is made greater.



Building the G2 reactor —bending the cable strands and fixing them to the anchor heads

Free from Danger

It is seen at once that immediately the internal pressure is removed from the pressure vessel, leaving the tensioned hoops, the concrete is then subject to the highest stresses. The situation is, in truth, free from danger. The maximum stresses are, moreover, soon lost in the thickness, without having to bring in the phenomenon of concrete extrusion. Finally, the limit adopted for the project, 1,422 lb/sq.in., is current practice, and is even found in some vault dams with extensive surfaces.

For the cupolas, the first approximation consists in assuming them to be thick, spherical cupolas perfectly bedded at the circumference. The calculation gives in direction and in intensity the meridian thrust due to the pressure and due to circular hoop

binding. The number and the position of the hoops required are deduced from this.

The third system of cables, which pull the cupolas on to the cylindrical body, is immediately determined.

Shape Unimportant

Consideration of the true shape of the pressure vessels leads to adjustments in the calculations just described, but does not, however, lead to great modification of the cable systems, which is explained by the fact that, whatever may be the shapes, prestressing is always directly opposed to the pressure. On the other hand, taking into account the connection between parts enables it to be determined in what order tensioning should be carried out to avoid trouble, more particularly with regard to the shrinkage joints and in the cupola surrounds.

The preceding calculations enable the intensity, assumed to be uniformly distributed, of the prestressing forces strictly necessary in the case of a given pressure to be arrived at.

Separate cables have, of course, to be used. Having fixed the unit force at a maximum of 1,200 tons so as to reap the benefit of practical knowledge obtained from previous constructions, the spacing is at once deduced.

Tensioned Tighter

The cables were all tensioned tighter, in accordance with usual practice, with a view to guard against slackening of the strands and concrete extrusions. Additional over-tension was put on to the hoops to compensate for friction loss between skid and slide-plate. An even further factor of safety was provided by *a priori* over-estimation of the coefficient of friction (0.05 per cent.) in relation to the repeated laboratory tests, which had given extremely low values for the arrangement decided upon.

The increases in tension were obtained by working on the number of strands and not on their working stress. The latter was taken at about half the figure guaranteed by the supplier, that is, 44.5/47.5 ton/sq.in., which is low for prestressing.

Expansion of the vessel due to the pressure causes over-tension. A simple elasticity calculation enables this to be estimated at a few ton/sq.in. for the test pressure alone. Safety in service is therefore ensured.

It appears most unlikely that the pressure would accidentally exceed its working value and, furthermore, it is not known in what manner it would do so or at what speed. But it is nevertheless interesting to examine how, and how far, the prestressed vessel would be capable of resistance.

As long as the pressure remains below that value at which it exactly balances the prestressing forces, the concrete will be in compression or, at the worst, in the neutral state. If the pressure rises above this value, the tensile strength of the material comes into play; this is fairly low, but, in view of the great thickness, the corresponding force is not to be despised. Therefore, assuming a limit of 569 lb/sq.in., the concrete would only yield at an over-pressure of the order of 50 per cent. of the test pressure. Nevertheless, it should be noted that the calculation assumes homogeneity of the material, and that this homogeneity is at least broken at the shrinkage joints between cylinder and cupolas. It is probable that these would yield at a lower value of over-pressure.

Apart from this reservation the elasticity calculation is correct, seeing that the cables would still only be overloaded by about 6 ton/sq.in., which leaves them in the zone of small elongations.

If Strain Was Too Much

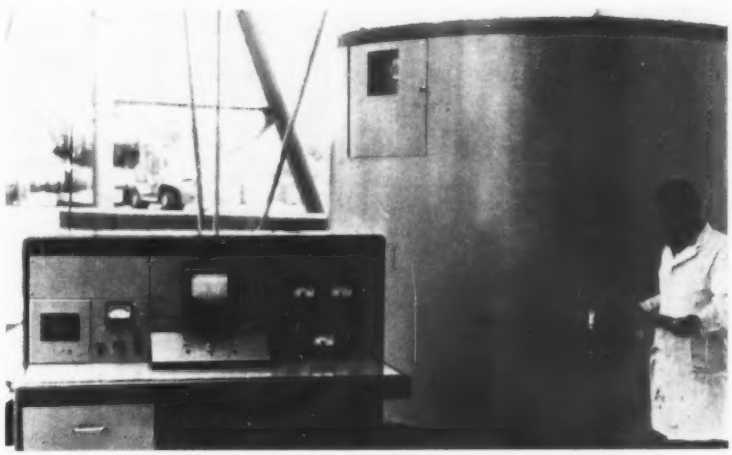
Above this value the concrete would bring nothing further to the task, and the whole load would be taken by the cables, which would then be subjected to even greater elongations. Splitting would then be progressive but, in view of the thickness, the casing would only break up into very big pieces, so that the steel plate lining would still be efficiently held.

Finally, total rupture would occur when the cables yielded, which enables the fatal pressure to be put at about double the test pressure.

This argument assumes that the cables' anchors would not give before the cables themselves. This has been taken care of, and preliminary tests proved that this is in fact the case.

This article is a translation from *Bulletin d'Informations Scientifiques et Techniques*, published for the Commissariat a l'Energie Atomique.

Laboratory Research Reactor



Atomics International, a division of North American Aviation, Inc., in the United States, has recently developed a new nuclear research reactor. The new reactor is actually one of six 10w nuclear research reactors being constructed solely for training and research programmes for educational and medical institutions and industrial laboratories. One of them is operating at the company's plant in Canoga Park, California. It was developed after more than 700 hours operational experience with a prototype unit, the L-47 Laboratory Reactor. The new Laboratory Reactor is only 8 ft high and 8 ft in diameter and can be installed in a laboratory without adding special facilities. It is relatively inexpensive and can be manufactured, installed and prepared for operation in a short time. Fuel for the reactor consists of enriched uranium and is contained in a stainless steel core vessel.

PEOPLE... in the NUCLEAR NEWS

Appointed personal adviser to Sir Leonard Owen, managing director of the United Kingdom Atomic Energy Authority Industrial Group is **MR. H. G. DAVEY,** OBE, MSc, FRIC, formerly works general manager of the Authority establishments at Windscale and Calder Hall. At one time a lecturer in chemical engineering at Cardiff University, where he was educated, Mr. Davey joined the Ministry of Supply in 1940 as a chemical engineer and two years later became manager of the Royal Ordnance Factory at Drigg. In 1944 he was

Mr. H. G. Davey

Mr. T. Tuohy

appointed deputy superintendent of the Drigg Sellafield-Bootle Group and in 1946 became superintendent. He went to Windscale in 1947. Mr. Davey's post as works general manager at Windscale and Calder Hall has been filled by his deputy, **MR. THOMAS TUOHY,** BSc. Among Mr. Tuohy's previous appointments with the Atomic Energy Authority have been the managerships of the Windscale Reactors and Plutonium Metal Production Plant and of the Springfields factory.

Metropolitan-Vickers Electrical Co., Ltd., have appointed **MR. A. WEST,** AssocMCT, HonMSc (Manchester), MIMechE, MIEE, as assistant managing director of the company. Mr. West joined Met-Vick in 1918. He became chief engineer of the motor and welding departments in 1940 and six years later was made assistant to the chief electrical engineer. He became chief electrical engineer in 1949 and was appointed to the board in 1951. Mr. West ceased to be chief electrical engineer in 1957 so as to permit him to devote more time to the affairs of the A.E.I.-John Thompson Nuclear Energy Co., of which he was appointed managing director in 1956. He was associated with the A.E.I.-John Thompson Nuclear Energy Group from its inception, and was chairman of its management committee.

MR. R. D. GARDINER, formerly associated with the industrial group of the UKAEA and responsible for contracts, purchases and control stores, has now been appointed assistant chief contracts officer of the Central Electricity Generating Board.

Power Jets (Research & Development), Ltd., have appointed **MR. N. M. CLARK,** BSc(Eng), ACGI, AMIMechE, to be their chief engineer in succession to Mr. J. Hodge. He joined the firm as a senior engineer in the consultancy department in 1955. Previously he was apprenticed to W. H. Allen, Sons & Co., Ltd., where he was closely associated with the design of the first Allen gas turbines, being later appointed gas turbine development engineer. His consultant work with Power Jets has included responsibility for the design and development of the Rankin & Blackmore turbine in the T. W. Morar and the design of circulators for gas-cooled reactors.

MR. L. GRAINGER, BSc, AMInstMet, is to succeed Dr. H. M. Finniston, BSc, PhD, ARIC, as head of the metallurgy division in the UKAEA's research group at Harwell. Mr. Grainger joined the AEA in 1952 and later became head of the research and development laboratories at Springfields. In 1955 he moved to Risley as chief

Mr. L. Grainger

metallurgist in the research and development branch and in 1958 became deputy director. Mr. Grainger made contributions to the 1955 and 1958 Geneva Conferences and to the Calder Hall Symposium in 1956.

New general works manager of Ferranti, Ltd., is **MR. A. J. GRAY,** BSc, AMIEE, who was previously works manager of the transformer department. This post is now held by **MR. G. R. C. McDOWELL,** BSc. Mr. Gray's appointment followed the retirement of **MR. W. HUNT,** MBE, JP.

The Nuclear Power Plant Co. Ltd., have announced that **MR. R. EDWIN McALPINE** has been elected chairman of the company in succession to the late Sir Claude D. Gibb.

Mr. R. Edwin McAlpine
(Photo by Lotte Meiner—Graf ARPS)

Vice-chairman of the NPPC since its inception, Mr. McAlpine is a partner in Sir Robert McAlpine & Sons, the controlling firm of several companies, including the civil engineering company of the same name.

DR. J. A. L. BONNELL, MB, BS, MRCS, LRCP, senior medical officer at the Central Electricity Generating Board, has been appointed nuclear medical officer and deputy to Mr. C. A. Adams, chief nuclear health and safety officer of the Board. Before joining the Generating Board, Dr. Bonnell was assistant physician in the Medical Research Council's department for research in industrial medicine at the London Hospital.

Four new managerial appointments have been announced by The English Electric Co., Ltd. **MR. E. B. BANKS,** AMIEE, has been appointed director of commercial policy, contracts and sales; **MR. P. L. de LASZLO,** OBE, has been appointed director of corporate affairs; **MR. W. M. HURTON** has been appointed director of group manufacturing development and **MR. L. H. SHORT,** MC, MIEE, MInstT, has been appointed director of overseas operations.

MR. G. BUCKLAND-SMITH, who has been responsible for many UKAEA film productions, has been appointed managing director of Greenpark Productions, Ltd. He joined the firm in 1955 and became a director last year. Among Mr. Buckland-Smith's productions for the Authority is the highly-praised "Criticality," which has been shown to audiences throughout the world and won awards at several film festivals.

HEAT INTO ELECTRICITY

American "Thermo-Electron Engine"

Dr. George N. Hatsopoulos (*left*) and Dr. Joseph Kaye of the Department of Mechanical Engineering at the Massachusetts Institute of Technology hold a model of the new device they have invented for converting heat directly into electricity. Called a thermo-electron engine, the model operates without any mechanical moving parts and may become practical for many purposes—including the more effective use of atomic energy in small power plants

AN engine that would convert nuclear heat into electricity is in great demand nowadays. Two American professors, namely George N. Hatsopoulos, assistant professor, and Joseph Kaye, professor of mechanical engineering at the Massachusetts Institute of Technology, have recently invented just such a machine.

Their new device, a "thermo-electron engine" which operates without any moving mechanical parts, is based on the principle that if two metal plates are placed side by side and one is made hotter than the other, electrons jump from the hot plate to the cold plate. They form a stream of electricity which can be used for any electrical purpose.

Thus far, the process has been conducted only inside a large vacuum tube, but the inventors have applied for a patent on the device and they believe it will become practical for many uses.

Five Year Study

A kind of heat engine that uses an electron gas instead of steam, the invention has been under development over the past five years by the Massachusetts Tech's professors whose latest working model is based on a scientific report which was published by Professor Hatsopoulos not long ago, and which was the first detailed study of such an engine ever made.

A device of this kind has several advantages over the old-fashioned steam engine or the modern steam turbine or even a nuclear power plant in which heat is converted to electricity by means of a steam turbine.

Because it uses no rotating machinery to convert heat to electricity, it should be vitrually maintenance free.

Whenever size and weight are a consideration—as they are in missiles and satellites—it will have significant advantages over conventional systems.

And on the basis of efficiency alone, it should be more than competitive in the small power plant field.

"Now that we have a working model," says Professor Kaye, "it appears that a relatively simple electron heat engine can be built using ordinary fuels, nuclear fuels, or solar energy."

"And 'isotope heating'," Professor Hatsopoulos adds, "is a very promising possibility for the near future."

(Isotopes which are made radioactive, or charged up as it were, in a nuclear reactor give back this energy in the form of heat. Since some of these radioactive isotopes have a long life, they could readily be used as a heat source for a thermo-electron engine).

1,200°F. Difference

Basically the electronic heat engine consists of two metallic plates—one relatively hot and the other relatively cold—inside a vacuum tube similar to a radio or television tube.

Heat is applied to one of these plates at about 2,200°F. This is the hot plate. The other plate, which is spaced only about $^1/_{1000}$ in. away, is maintained at about 1,000°F. Though still very hot, this is the "cold" plate.

12 Per Cent. Efficiency

In operation, electrons are boiled off the hot plate on to the cold. When the plates are connected by a wire outside the tube with an external load, the electrons are conducted off to produce useful work.

The model of the new type heat engine has produced electric power with thermal efficiencies of about 12 per cent. This conforms closely with the theoretical predictions made by Dr. Hatsopoulos in the first basic study of this phenomenon and the inventors of the device feel that efficiencies of about 30 per cent. may eventually be obtained.

The professors are also investigating another thermo-electron engine which uses crossed electric and magnetic fields to control the flow of

electrons. They predict that this device may attain even higher efficiencies than their present model.

" Even on the basis of the current model it appears that a relatively efficient power plant can be built to yield from 5,000 to 15,000 watts/cu.ft of total plant volume with a probable thermal efficiency of better than 10 per cent."

More Study Needed

But this does not mean that electron heat engines will be in use tomorrow. A lot of development work lies ahead before they can be put into commercial operation. This will be undertaken by the Thermo-Electron Engineering Corporation of Cambridge, Massachusetts.

" Many small power plants have low operating efficiencies and the thermo-electron engine may be competitive with them even now.

" These engines might be used in satellites where weight is a primary consideration or in missiles where their instant operating readiness and lack of mechanical parts would be an advantage."

Analogy to Steam Plant

The new device is called a "thermo-electron engine" because basically it is a heat engine that uses electrons instead of steam or some other working fluid. In all heat engines, a working fluid goes through a cycle in which heat is exchanged between two or more temperature reservoirs and useful work is delivered to the outside.

In most conventional steam power plants, for example, steam is used as the working fluid of the heat engine. It receives heat from hot combustion gases, it delivers electrical work through a turbine-generator combination, and it rejects heat to cooling water in the condenser.

In the electron heat engine the working fluid is composed of electrons. But the cycle of events is similar to that for steam in a conventional power plant.

Free electrons, found in most metals are forced to leave a suitable metal by heating it to a high temperature such as 2,000°F. The heating creates a stream of " hot " electrons, some of which possess sufficient energy to overcome a potential barrier or an applied voltage. This tends to slow down these electrons and so provides a means of extracting directly useful energy in the form of electrical output.

Nothing Moves

The electrons which overcome this applied voltage are collected in another metal and heat is rejected from this metal to the surroundings. The useful electrical output is obtained by connecting the hot metallic surface externally through a load to the cold collecting surface.

Thus the electron gas goes through the typical heat engine cycle of receiving heat at a high temperature and rejecting it at a lower. But unlike the typical system it achieves a useful work output directly with no moving parts.

HUNGARIAN NEWSLETTER

"Need for Co-operation"—Soviet View

MOVES are afoot for even closer co-ordination of atomic research between the socialist countries. This was indicated by Professor D. I. Blohinchev, director of the United Atomic Research Institute at Dubna in the Soviet Union, during a recent visit to Hungary.

The Dubna Institute is the common research laboratory of 12 socialist countries. It deals mainly with the examination of the properties and effects of accelerated particles and possesses the highest powered accelerator in the world.

" At present," Professor Blohinchev said, " 11 young Hungarian research scientists are working at Dubna. During their work each contributes to the building of the science of nuclear physics. Joint work means joint success.

" Each of the countries participating have their own national physics laboratories doing very valuable work. Hungary for instance, with modest means, is carrying out valuable research work that has yielded results worthy of international recognition.

" It is for this very reason that it is necessary that the work of the United Atomic Research Institute and the national institutes should be harmonized. This is to the joint interest of research scientists and the whole socialist camp.

" Scientific work carried out simultaneously but independently means an unnecessary loss to the community. If a unified direction can be evolved so that we know precisely who is doing what and what he achieves, then the abilities of every research scientist can be used to the best interests of the individual and the community."

* * *

Following upon his visit to the Hungarian Atomic Physics Research Institute Professor Blohinchev said that although it is difficult to achieve original or great results in the field of neutron physics on a small budget, he felt that Professor Lénárd Pál, the deputy director of the Institute, and his small group of co-workers, had obtained valuable results likely to be of use in reactor building.

He then went on to commend the work of Professor Ervin Fenyves' group at the Hungarian Central Physical Research Institute, which is specializing in the construction of instruments for nuclear physics research and which has automated certain processes relative to the examination of high speed particles.

He had also been impressed with the research on the nature of light being carried out by the scientists working with Academician Lajos Jánossy, the director of the Central Physical Research Institute.

At the Debrecen nuclear research institute of the Academy of Sciences Professor Blohinchev had seen the work carried out under the direction of Professor Sándor Szalay, research into the heavy element atoms, which he felt might be termed biogeochemistry.

Basing his opinion on what he had seen during his visit Professor Blohinchev said that co-ordination of research work should be as wide as possible: closer co-operation would be to the greater benefit of the scientists of the socialist countries.

He gave as an example of co-operation the fact that when Academician Jánossy recently needed knowledge of the behaviour of certain highly energized high-speed particles the research was carried out in Dubna and the information was supplied in two weeks.

Speaking about atomic reactors in the Soviet Union, Professor Blohinchev said, " We have built and are building several types of atomic reactors and experience will prove which type is best. This experience is the common wealth of the socialist countries—future reactors to be built by different countries for the production of electric power can be based on this experience.

" For us an unsuccessful experiment means only a temporary inconvenience but it could bankrupt the economic life of a little country....this is why co-operation between the socialist countries is a matter of sound common sense.

" We at the United Atomic Research Institute in Dubna await the reports of Hungarian scientists, engineers and workers with interest and have already invited them for such exchanges of ideas," concluded Professor Blohinchev.

NUCLEAR ENERGY DEVELOPMENTS IN EUROPE

POLAND and RUSSIA

Although power stations to be built in Poland during the next 15 years or so will largely be coal and lignite fired, considerable interest is shown in the development of nuclear energy and activities for the first phase of a nuclear programme have already started. In Russia there are plans for building nuclear power stations where conventional forms of fuel are in short supply or obtainable only at great expense.

by J. BURKETT

POLAND

POLAND'S economy, based on rich deposits of coal, is considered to be assured for another 100 years. Lignite is also available and, although its use is not considerable at the moment, it is expected to play an increasing part in future energy supplies. Current electrical energy production *per capita* is just over 650 kWh per annum, though this is expected to rise to 1,313 kWh by 1965 and 2,340 kWh by 1975. Large capital investments will be necessary to reach the 1975 target and the main effort will probably be directed to the construction of coal-fired steam power plants and the development of lignite plants.

Nevertheless, complete reliance on the coal and lignite mining industry to satisfy all the requirements for electrical energy for the next 20 years is considered to be undesirable, particularly in view of an expected steady increase in coal prices. Although Poland will not have to take up nuclear power as soon as other European countries, first phase activities have already commenced in preparation for a nuclear development programme. Poland is anxious to export its coal, the target for 1965-70 being about 20m. tons per annum. Any coal saved by the use of nuclear power will help the export target.

U.S.S.R. Reactor

Poland's first research reactor which started up in 1958, was supplied by the U.S.S.R. and is a 2 MW water-moderated reactor fuelled with 10 per cent. enriched U-235. A second research reactor is planned for 1962-3 and this will be a gas-cooled graphite type. The first generation of power reactors will be natural uranium-graphite moderated, gas-cooled and the first of these, a 200 MW station, is expected to be operating, with Soviet assistance, in 1965. By 1970 estimated total installation will be 800 MW, followed by a further 1,000 MW for the period 1970-75. After this period all further increase of production capacity will most likely be covered by nuclear power plant.

The second generation of reactors will be fast breeders using the uranium-plutonium cycle and thermal reactors enriched with plutonium from the power reactors of the first generation. Poland's known deposits of uranium are said to be sufficient to cater for all the requirements of the first stage of nuclear power plant development—processing techniques are now in the development stage.

Further details can be obtained from the following papers presented at the 2nd International Conference on the Peaceful Uses of Atomic Energy:—P/1593—Perspectives of the Polish nuclear energy programme; P/1940—Conditions of the economic operation of nuclear power stations in Poland.

RUSSIA

RUSSIA has vast resources of organic fuels and water power (estimates: coal reserves—300,000m. tons; natural gas—13 billion cu.m), but there are regions with existing or planned industrialization that have no supporting local fuel resources. In these areas and, in particular, the industrialized and European part of Russia, nuclear power is likely to be an economical proposition.

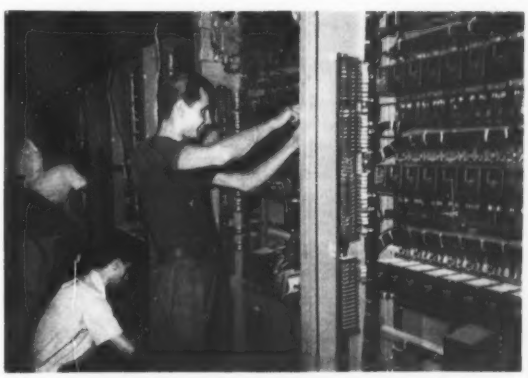
Consequently, the current and the following five-year plan provide for nuclear power stations in Siberia, the Urals, Voronezh, Leningrad and the Volga with a variety of reactor systems including graphite moderated water cooled, pressurized water moderated and cooled, boiling water, sodium-graphite, boiling heavy water and fast reactors.

New Ministry

Reactor development up to now has been determined by the Academy of Sciences but it is likely that with the formation of the Ministry of Power Stations all future development for electrical expansion will be co-ordinated by the new Ministry.

The first experimental nuclear power station to operate in the U.S.S.R., a 5 MW(e) pressurized water cooled thermal uranium graphite reactor, has been generating electricity at Obrinskoye for four years. (For detailed description see NUCLEAR ENERGY ENGINEER, June to August, 1958.) A scaled-up version of this reactor, APS-1, designed to give 100 MW(e) at full power, became critical in 1958. It is the first of six units, for the future 600 MW nuclear power station, power from which will be used for the industrialization of Siberia.

Progress in the design and development of pressurized water reactors is considered to be equal to work done in the U.S.A. This type of reactor is also being designed into the nuclear power stations for Voronezh and Leningrad and used for the propulsion



Assembly of components of the cyclotron recently set in operation at the Cracow Institute of Nuclear Research

of an icebreaker. In the *Lenin*, two reactors will supply all the steam for propulsion units, having an output of 42,000 h.p. The weight of the nuclear plant will be 1,054 tons, that for shielding 1,963 tons whilst the propulsion plant will weigh 2,750 tons. With each core designed for full capacity operation for about one year, endurance at top speed is estimated to be two to three years.

Small Stations

According to Professor Emelyanov at Geneva, Russia is also developing small mobile pressurized water 2 MW stations for areas of new industrial development where there are temporarily no sources of electrical power.

The industrial use of fast reactors has been investigated since 1949. Design studies carried out during 1950-51 using different heat transfer agents: sodium, sodium-potassium, lead-bismuth alloy, and helium, proved the feasibility of such systems.

First Fast Reactor

The first fast reactor, BP-1, was used to check the theory of fast reactors and to study the characteristics of fast neutrons. Whilst this operated at only a few watts and used no heat transfer agent, BP-2 had a maximum power of 100 kW for more advanced nuclear investigations and materials testing. Mercury was used as the coolant only because of lack of working experience with sodium-potassium eutectic. BP-5 is intended to bridge the gap from BP-2 to a commercial-size power producer and it will be used for research on fuels and materials, particularly sodium. The 50 MW(e) experimental power unit, BN-50, which is in the design stage, will be followed by BN-250, a typical industrial nuclear power station, after the former has been proved.

Further details can be obtained from the following papers presented at the 2nd International Conference on the Peaceful Uses of Atomic Energy:—P/2185—New and modified experimental reactors; P/2502—Experimental reactor with gaseous substance UF6; P/2183—Operation of the first U.S.S.R. atomic power station with fuel channels working in boiling conditions; P/2139—Uranium-graphite reactor with superheated high pressure steam; P/2184—Pressure water power reactors; P/2140—Nuclear propelled icebreaker; P/2518—Atomic icebreaker radiation safety problem; P/2142—Uranium-water intermediate reactor used for obtaining high-intensity neutron fluxes; P/2038—Physics of fast neutron reactors; P/2129—Experimental fast reactors; and P/2298—Investigations on controlled thermonuclear reactions.

TABLE OF RESEARCH AND POWER REACTORS OPERATING, UNDER CONSTRUCTION AND PLANNED IN THE U.S.S.R

	Fuel	*Thermal Power*	*Net Electrical Output*	*Moderator*	*Coolant*	*Maximum Flux*	*Steam at Turbine*	*Start-up*
Research Reactors								
RPT	90% enr.	3 MW	—	Graphite and H_2O	H_2O	1.8×10^{14}	—	April, 1952
WWR-2 (Tank Type MTR)	10% enr.	3 MW	—	H_2O	H_2O	4×10^{13}	—	Operating
TR	2%	2.5 MW	—	D_2O	D_2O	2.5×10^{13}	—	April, 1949
IRT (Swimming pool)	10%	2 MW	—	H_2O	H_2O	3.2×10^{13}	—	
WWR-M	20%	10 MW	—	H_2O	H_2O	1×10^{14}	—	
WWR-Z	20%	10 MW	—	H_2O	H_2O	1×10^{14}	—	
Power Reactors								
APS-1 Obrinskoye	5% enr.	30 MW	5 MW	Graphite	H_2O	5×10^{13}	270-280°C. 1,470 lb/sq.in.	June, 1954
Siberia	Nat. U.	—	600 MW (6 reactors)	Graphite	H_2O	—	185°C. 90 lb/sq.in.	Sept., 1958
Uranium/Graphite Urals	1.3% enr.	—	400 MW (4 reactors)	Graphite	H_2O	—	480-500°C. 1,320 lb/sq.in.	Under construction
PWR Voronezh	1.5% enr.	—	420 MW (4 reactors)	H_2O	H_2O	—	275°C. 430 lb/sq.in.	1961
PWR Leningrad	1.5% enr.	—	420 MW (4 reactors)	H_2O	H_2O	—	275°C. 430 lb/sq.in.	
BWR Ulyanov	1.5% enr.	—	50 MW	H_2O	H_2O	—	230°C. 480 lb/sq.in.	
Boiling Heavy Water Volga	UO_2 suspended in D_2O	35 MW	—	D_2O	D_2O	—	—	
Sodium/Graphite Volga	Various	—	50 MW	Graphite	Sodium	—	500°C.	
Intermediate	—	50 MW	—	—	—	—	—	
Mobile PWR Obminsk	—	—	2 MW	H_2O	H_2O	—	280°C. 290 lb/sq.in.	
Lenin Icebreaker	5% enr.	270 MW (3 reactors)	—	H_2O	H_2O	—	310°C. 430 lb/sq.in.	Spring, 1959
Gaseous fuel	UF_6	Nil	Nil	Beryllium	Uncooled	—	—	1957
Fast Reactors								
BP-1	Plutonium	10 w	—	—	No coolant	—	—	1955
BP-2	Pu	100 kW	—	—	Mercury	10^{14}	—	1956 (dismantled)
BP-5	Pu oxide	5 MW	—	—	Sodium	10^{15}	—	
BN-50 Volga	Pu-U alloys	200 MW	50 MW	—	Sodium	10^{16}	—	
BN-250	Pu	—	250 MW	—	Sodium	1.3×10^{16}	—	

NUCLEAR NEWS

- **U.S. Firm Offer 330 MW Plant** *(This page)*
- **Euratom Requirements** *(Page 158)*
- **I.A.E.A. Mission to East** *(Page 159)*

THE Westinghouse Electric Corporation has announced that it is prepared to develop, design and manufacture the equipment for a 330,000 kW nuclear power plant. The plant would be of an advanced pressurized water reactor design. The disclosure to the electric utility industry that Westinghouse was ready to embark on such a project was recently made by Charles H. Weaver, vice-president in charge of atomic power, who said, "We believe this plant will produce power at costs competitive with fossil fuels in the higher fuel cost areas of the United States. He emphasized that the proposal for a 330,000 kW plant was part of the company's broad, multi-front programme to develop economic and useful atomic power. We do not believe that any one reactor is best for all sizes and locations, for all times, and for all requirements," he said "Because of this the Westinghouse development programme offers a choice of reactor types. The pressurized water reactor already has gone through three generations of plants—the Nautilus prototype in Idaho, the first large U.S. atomic power plant at Shippingport, Pa., and the Yankee Atomic Electric Co., plant now under construction at Rowe, Mass." The proposed 330,000 kW plant would be of the fourth generation.

S.T.E. Course at Harwell

FROM time to time courses for Senior Technical Executives in industry are held at the Harwell Reactor School. The next of these courses on which places are available will be held from June 15th-25th, 1959. The fee for the course is 50 gns. exclusive of accommodation and those who are interested should apply for application forms and details from: The Principal, Reactor School, Atomic Energy Research Establishment, Harwell, Didcot, Berks.

Translation Service

TO provide British scientists and engineers with up-to-date information on the availability of English translations of Russian technical papers and journals, the Department of Scientific and Industrial Research have introduced a monthly bulletin on the subject. Compiled by the Department's Lending Library Unit, the publication is called "The LLU Translations Bulletin" and it lists all scientific literature which is either already translated or is being translated to become available in the near future. One section of the Bulletin deals with cover-to-cover translations—a scheme for providing a complete Russian technical journal in the English language—and another section gives details of the work being carried out by the National Science Foundation in the U.S.A., (many translations from America are held in London on microfilm and copies may be borrowed). The Bulletin also contains articles on new scientific developments in Russia.

Film Gift

EURATOM has been presented with a library of British films on nuclear energy. The presentation took place after the signing of the recent agreement between Britain and Euratom on the exchange of information and was made by Sir Edwin Plowden, chairman of the Atomic Energy Authority. The 17 films that made up the gift were contained in a special cabinet, which was received on behalf of Euratom by Professor E. Medi, of Italy.

Another Reactor

A 15 MW experimental nuclear reactor is to be built for the West German government by a subsidiary company of the Krupp and Brown Boveri Industrial Combines it has been reported. The reactor would be at Juelich, between Cologne and Belgium, and building would take four years, adds the report. It would be the second demonstration nuclear power station in West Germany. The research scheme will cost about £3,400,000, half being met by 10 electricity undertakings and the rest by the Federal Government. Under the Krupp-Brown Boveri design, gas heated by passing over the reactor will drive the turbines instead of steam.

U.K. Reports on Microfilm

CERTAIN non-secret reports on nuclear subjects prepared by the United Kingdom Atomic Energy Authority are now generally available on microfilm and copies can be bought direct from Micro Methods Ltd., of East Ardsley, Wakefield, Yorks. The scheme covers all unclassified and declassified reports issued between 1947 and 1956 and on a continuing basis, all non-secret reports issued since 1956 which are not available for sale in printed form from the Stationery Office. A complete set of 1956-57 reports costs £120, and of those issued between January, 1957, and June, 1958, £14. A complete set of reports issued between July, 1958, to June 1959, will cost £9. Microcopies of individual reports can be bought at a cost of 2s. per card. A list of all reports available may be obtained from Micro Methods.

AFTER PACT—A CHAT

Foreign Secretary the Rt. Hon. Selwyn Lloyd chats with Euratom Commissioner Professor E. Medi, of Italy (*centre*) after they have signed an agreement on the interchange of nuclear information between Britain and Euratom. With them is Professor De Groote, another Euratom Commissioner. The agreement provides for full exchange of unclassified information between the Atomic Energy Authority and Euratom and it codifies the terms on which nuclear power stations and the fuel for them shall be supplied from Britain to any of the six member countries of Euratom

Euratom Requirements

DR. HEINZ KREKELER, an Euratom commissioner has said that the six Euratom countries would require about 24 nuclear power reactors during the next six years. Six would probably be provided by the United States, but the market for the others would be "wide open" to firms in Britain or elsewhere. He stressed that his commission was not a buying agency, and that negotiations for the sale of reactors, equipment and fuel would be between the British contractors and the public and private utility companies which were to operate the reactors in France, Western Germany, Italy, and the Benelux countries. "As a very conservative estimate we shall need reactors to provide 4,000 MW of power," he said. Of this only 1,000 MW (or six reactors) were accounted for in the agreement with the United States. Another member of the commission, Mr. E. M. J. Sassen, pointed out that the reason the American agreement mentioned a specific number of reactors was that the American Government had offered the Euratom countries credit for $135m. for their installation, because "America wants to benefit from our experience in operating industrial reactors." The British Government, however, had not offered credit terms, nor had his commission asked for them. "Quite understandably, the British Government thought the export of British reactors and fuel—and the possible arrangement of credit terms—should be left to the British firms and the Euratom countries."

Reactor for U.S. Army

THE American Army has placed an order with ALCO Products Inc., for a nuclear power plant based on the design of the Army Package Power Reactor (APR—1) in operation at Fort Belvoir, near Washington. Price of the contract is in the region of $3¼m. The new plant will be used to provide heat and power in remote locations and will be designed to be moved by air transport in 20 to 30 modules or packages. Concrete construction for shielding will be unnecessary. Electrical output of the new plant will be 1,500 kW and output of steam that can be used directly for heating purposes 1,000 lb/hr. Unlike its prototype, the new plant will be cooled by means of an air and ethylene glycol system; APR—1 at Fort Belvoir uses water drawn from the Rotomac River. Fuel for the new plant will consist of uranium oxide clad with stainless steel. A team of 15 men will be required to operate the plant.

Address Change

THE address of the British Insulated Callenders' Cables Ltd., branch office at Derby has been changed to, Hartington Street, Derby. The telephone number remains the same, Derby 41421.

Premier at Thornaby

The Prime Minister, the Rt. Hon. Harold Macmillan, asks questions about one of the boilers being built by Head Wrightson & Co., Ltd., for the Bradwell nuclear power station. Mr Macmillan was visiting the firm's Thornaby-on-Tees works during his recent tour of North East England. To commemorate the visit he was presented with a book describing the novel method of transportation used in getting the boilers to Bradwell

Reports Given Away

COMPLETE sets of microfilm copies of unclassified and declassified reports on nuclear subjects prepared by the United Atomic Energy Authority between 1947 and 1956 have been presented to the International Atomic Energy Agency, the European Nuclear Energy Agency, Euratom and countries with which the Authority has active report exchanges.

Manipulator Exports

MASTER slave manipulators for the remote handling of radioactive materials have been ordered from Savage & Parsons Ltd., of Watford, Herts., by Negretti & Zambra (South Africa) Ltd., for display at the Rand Easter Show, which is being held in Johannesburg during March. The manipulators will be shown in action in a demonstration "hot cave" and are expected to be one of the highlights of the exhibition. Other export orders recently received include pairs of manipulators for the French Commissariat de L'Energie D'Atomique, and for the Belgian Centre D'Etude de L'Energie Nucleaire at Mol-Donk.

I.A.E.A. and N-Fuel

SAFEGUARDS intended to prevent the loss or diversion of source and special fissionable material from peaceful purposes and to avoid hazards to life and property will be applied by the International Atomic Energy Agency to its assistance project for Japan, according to a recent decision of the IAEA's Board of Governors. Under this project the agency is selling to Japan three tons of natural uranium to be used in a research reactor on condition that the IAEA's statutory safeguards requirements are met by Japan. The draft of a relevant agreement between the agency and the Japanese Government has been approved in principle by the board of governors. For some time the agency has been working on a series of safeguards procedures which cover accounting, measurement, stocktaking and safekeeping measures to prevent any loss or diversion of material used in atomic research or power programmes and to avoid hazards to health. To this end, the agency is now placing research contracts in Belgium (with Centre d'etude de l'energie nucleaire), France (with the Commissariat a l'energie atomique francais) and in the United States of America for developing techniques for non-destructive analysis of irradiated fuel elements. These methods should make it possible to establish precisely, rapidly and economically the amount of U-235 contained and of plutonium generated in reactor fuel. The results of these studies will help in working out the safeguards procedures which the agency under its statute is required to establish and administer to ensure that special fissionable and other materials made available by the agency, or at its request, or under its supervision or control, are not used in such a way as to serve anything but peaceful purposes. The agency is further under the statutory obligation to establish standards of safety for the protection of health and minimization of danger to life and property. The agency will also provide advice to requesting member states on safeguard procedures for their specific requirements. The Japanese Government has already asked IAEA for assistance in setting up detailed accounting procedures for source and special fissionable material in that country.

New German Company

A GERMAN Company has been formed by the Graviner Manufacturing Co., Ltd., to look after the parent company's interests in Germany, the chief of which are airborne and industrial fire and explosion protection equipment, diesel engine oil mist detection and certain products in the nuclear energy field. The name and address of the new company, which is entirely Graviner-owned, are Deugra Gesellschaft fur Brandschutzsysteme m.b.H., Breite Strasse 3, Dusseldorf, West Germany.

Soviet Donation

A COLLECTION of scientific periodical literature has been donated by the Academy of Sciences of the Soviet Union to the International Atomic Energy Agency. Included in the gift are free subscriptions to 27 of the most important scientific periodicals published in the U.S.S.R. and the main Soviet abstract journals covering physics, chemistry, biology, astronomy and geodesy. Back copies of the abstract journals for the period 1955-58, in all more than 250 volumes, also form part of the donation.

I.A.E.A. Mission

AN International Atomic Energy Agency mission has been visiting Burma, Thailand, Indonesia and Ceylon to survey the conditions and the possibilities in the field of nuclear energy in these countries. The survey, which was undertaken at the request of the countries involved, is primarily concerned with a study of such sectors of industry, agriculture and general economy as are likely to be affected by the application of nuclear energy. Other fields of study are the use of isotopes in agriculture, biology and medicine, the development of reactor projects and a research programme, the training of technical manpower, health and safety standards and the availability of raw materials. Members of the mission were Dr. Hugh Belcher, head of the radio-isotopes laboratory of the post-graduate school at the Hammersmith Hospital, London; Dr. Georges Bigotte, geology expert with the French Atomic Energy Commission; Mr. Maheeshawr Dayal, design engineer with the Indian Atomic Energy Establishment at Trombay; Dr. Oleg Kazatschkovsky, Russian physicist and mathematician; Mr. Charles Beaumont, of the IAEA, Dr. W. Grigorieff, IAEA, Mr. Francois Pilker, IAEA, and Mr. Harold H. Smith, IAEA.

Nucleonics in Milan

Construction of facilities to house a 50,000w nuclear research reactor at the Enrico Fermi Nuclear Study Centre in Milan, Italy, nears completion. The solution-type reactor, designed and built by Atomics International, a division of North American Aviation, Inc., will be installed in the building on the left. Laboratories will be located in the two-storey section on the right. The reactor is scheduled to begin operating this summer

NUCLEAR NEWS

P.W.R. Link Up

A 5MW nuclear reactor plant for use at a power station now in operation near Saxon, Pennsylvania, is to be built by the Westinghouse Electric Corporation. The plant, which will have a pressurized water reactor, will be " hooked on " to an existing turbine generator. Owners of the station are the Pennsylvania Electric Co., of Johnstown, Pa., who with four other companies serve the General Public Utilities system. The other companies are the New Jersey Power and Light Co., the Jersey Central Power and Light Co., the Metropolitan Edison Co., of Reading, Pa., and the Manila Electric Co., of Manila, Phillipine Islands. Westinghouse have retained Gilbert Associates, Inc., as sub-contractors for engineering and construction of the reactor plant. Engineering is already under way and construction is expected to begin in May.

A First Sale

THE first sale of Lockheed Aircraft Corporation's newly-formed Nuclear Products Branch of the Georgia Division is a sub-critical nuclear reactor for the University of Texas. The reactor will be used in the university's new nuclear engineering curriculum being developed with the aid of the U.S. Energy Commission. Core of the reactor is 10 in. in diameter and 14 in. long and it uses two types of reflector-polyethylene and graphite. Lockheed won the order on a competitive bid basis.

U.K's. B.W.R.

A BOILING water reactor plant is to be built by the UKAEA for experimental purposes. It will be sited either at Windscale or at Dounreay. The decision to develop this type of reactor has been taken as a result of the recent international conference on the peaceful uses of atomic energy.

SNAP Preparations

Scientist testing the isotope polonium prior to its use in SNAP the 5 lb isotope generator developed by the Martin Co. More details of this reactor are given on page 131

'NUCLEARIST' writes . . .

NOWADAYS the general feeling is that modern means of communication have caused, figuratively, that is, a great shrinkage in our world. Mr. Ichiro Ishikawa, who headed the Japanese delegation to the Second Geneva Atomic Conference last year, seems to feel that this does not apply in the nuclear field. Japan's slow progress, especially in the research on thermonuclear fusion, he said recently, is due to a late start, as the result of his country's unfavourable position geographically. Remote from most other countries, except China, where secrets are well kept, Japan has been able to gain little from neighbours.

The situation demands reorganization of nuclear research in Japan, and an extension of the exchange of personnel with overseas countries. Given the opportunity to see the work of nuclear scientists in other progressive countries, the Japanese cannot fail to make good their late start, just as Germany has done; both countries have never been slow to take advantage of technological progress elsewhere.

* * *

Just across the Sea of Japan lies that mighty country which puzzles us just as much as does Russia, and which is politically linked to the latter country. Opinions may be divided over the physical and psychical effects of Communism upon a nation, but there can be no doubt that the Red countries are not to be counted among the technologically retarded lands. Russia's prowess in many scientific fields is quite beyond dispute. Now China shows evidence of a healthy expansion in research, that in the nuclear field being not the least.

Between 1952 and 1957 the number of research institutes in the Chinese Academy in Pekin increased from 31 to 68, the personnel increasing from 5,239 to 17,335, and the actual scientific staff from 1,292 to 5,506. Among the achievements may be included the huge increase in the manufacture of electrostatic generators, β-ray spectrometers, and other instruments for nuclear research. Also operating now in Pekin is Asia's largest research reactor, with a 7 MW output, while a 25 MeV cyclotron is another valuable tool. Needless to say, Russian help has not been a negligible contribution to this progress.

Lest Russian assistance in nuclear developments be taken simply as propaganda, it should be added that the U.S.S.R. is also giving a great deal of attention to its own power requirements, and in no unprogressive way. As G. W. Ermakov, chief engineer in charge of the Soviet's nuclear power stations, has declared, Russia is building at present five new stations, and a number of others will be soon started. One station, in the Urals, is using superheated steam with an efficiency of 37 per cent., the heat being generated in a uranium-graphite reactor. Near Voronesh there is being built a 420 MW station using two reactors of the pressurized water type, and a similar station is being built near Leningrad.

* * *

News from the U.S.A. can always be stimulating, and this is not least true of the new attempt to produce helium by a cheaper process than has hitherto been possible. Helium, the second lightest substance known to mankind, and a member of the "inert gas" family, finds several applications in nuclear fields. It has been much used as a coolant in research reactors, in arc-welding, low temperature work, and as a protective atmosphere above molten sodium coolants in reactors. It is now possible to win this valuable gas from natural gases by diffusion through glass capillaries. If the gaseous mixture, at 400°C. and 1,000 atmospheres pressure, is led into a chamber 1.5 cu.m in capacity, filled with glass capillaries, each 0.5 mm in diameter and 0.005 mm wall thickness, the helium diffuses through the glass, and in 24 hours 2,700 cu.m of the gas can be obtained from natural gas containing only 1 per cent. of helium, and quite free from impurities such as neon or water vapour. This method should do much to make the gas much cheaper and more accessible.

* * *

No such hope for increasing cheapness can be entertained in the case of some of the transuranic elements. Exciting though these man-made chemicals may be, and of such interest to chemists and physicists, they are doomed to become more and more expensive and inaccessible as their atomic numbers increase. In the case of berkelium, for instance, with an atomic number of 97, it has taken five long years of neutron bombardment of 8 gm of plutonium to produce a weighable amount of this element. Berkelium has been known only for 10 years, and its chemistry is still very much a closed book.

* * *

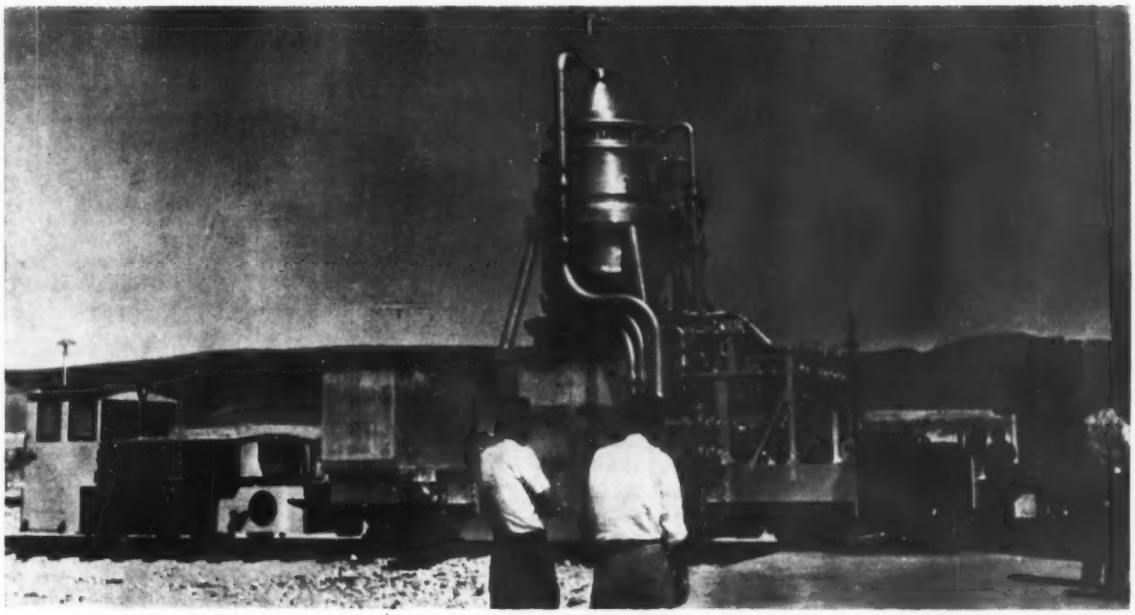
Could Sherlock Holmes take his place once more among the modern sleuths, I wonder if his long-suffering assistant, Watson, would have to carry a portable G.M. counter. The latest aid to criminology comes from the radiochemist! If formaldehyde (CH_2O) labelled with radioactive carbon-14 is applied to fingerprints, a condensation reaction occurs, and the product reveals the prints by means of autoradiography.

* * *

It seems a long time now since we saw that attractive type of glass, with a delightful yellowish glow, which was obtained by the use of uranium oxide in the batch. The advent of nuclear energy resulted in the prohibition of the use of this oxide, as might be expected, for anything other than nuclear energy work. Now that stocks of depleted uranium are building up, the U.S.A.E.C. has said that it may be used for industrial purposes once more. Deprived of this wonderful colorant since 1952, the glass-makers and potters may now once more turn to the making of the glass beautiful.

* * *

Once almost as expensive as diamonds was heavy water, now fast becoming a cheap commodity. Heavy water plants keep springing up all over the world. It has long been known, of course, that India, in making a long-overdue expansion of her fertilizer industry, had an eye on the possibilities of heavy-water as a by-product. Integration of such a sideline into the fertilizer plant seems a logical step. It is very disappointing to see, however, that the first plant in which this will be done, namely that at Bhakra-Nangal, is to be built not with British help, but by a German firm, Lindes Eismaschinen A.G., of Wiesbaden.



Nuclear rocket propulsion experimental test device known as "Kiwi-A" used in Project "Rover" at the Nevada test site

Projects

ROVER and PLUTO

THE U.S. ATOMIC ENERGY COMMISSION HAS RECENTLY BUILT TWO NEW RESEARCH LABORATORIES FOR THE SOLE PURPOSE OF STUDYING THE FEASIBILITY OF NUCLEAR PROPULSION SYSTEMS FOR ATMOSPHERIC AND SPACE VEHICLES

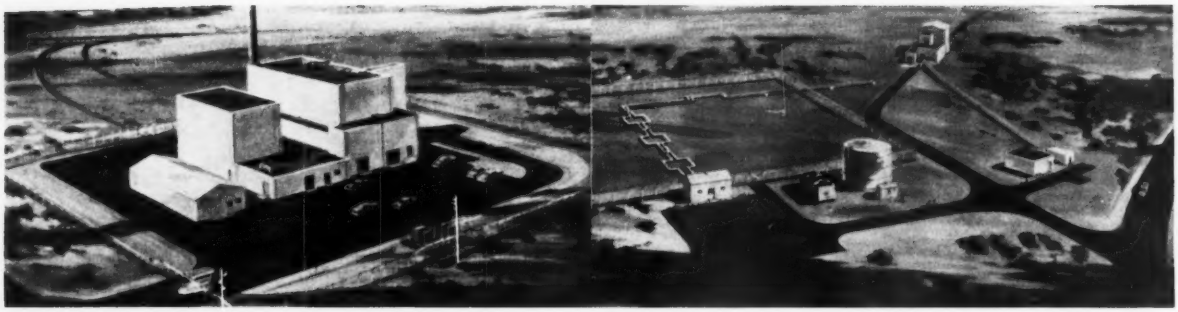
THE scientific theory that nuclear energy can be superior to chemical energy for long-range propulsion of man-made vehicles through the atmosphere or particularly through outer space was evolved soon after the fact of controlled fission was demonstrated.

In early 1955, the U.S. Atomic Energy Commission decided to go ahead with formal research programmes to determine the feasibility of nuclear propulsion systems for atmospheric and space vehicles. The programmes were assigned to the Los Alamos (New Mexico) Scientific Laboratory and to the University of California Radiation Laboratory at Livermore. Both laboratories are operated for the Commission by the University of California.

Planning began almost simultaneously for field experiment facilities where the two laboratories could test their reactor designs. Isolation was desired because it was foreseen that the experiments might result in the discharge of measurable amounts of radioactive particles into the atmosphere at the experimental site, and might also result in some ground contamination. The Nevada Test Site region was considered ideal for such a purpose because of the facilities, such as housing and feeding accommodation at Mercury, that already existed; because the existing Las Vegas Branch Office and its several contractors could provide administrative and site services; because U.S. Government-owned waste land was available in the area; and because it was within reasonable travelling distance from Los Alamos and Livermore.

Bombing Range Used

A 12-mile by 40-mile portion of the U.S. Air Force's Las Vegas Bombing and Gunnery Range was transferred to the U.S. Atomic Energy Commission. It is immediately west of the Nevada Test Site. Jackass Flats, which lies partly in the original site and partly in the new addition, was designated as the site for installations to support both the



Drawing of the maintenance, assembly and dis-assembly (MAD) building used in the nuclear rocket propulsion experiments at Nevada. Test reactors will be assembled in this building and then after experiments will be returned for dismantling and maintenance

Shown in picture is drawing of Test Area No. 1 at the U.S. Atomic Energy Commission's Nevada site where Project "Rover" experiments will be carried out. Top right of illustration is the Test Cell. (Drawings are by Burns & McDonnell Engineering Co., Kansas, Missouri)

Los Alamos and the Livermore programmes.

One section is designated the " 400 area " for Los Alamos, and another the " 401 area " for Livermore. Initial contracts for roads and water wells to serve both areas were signed.

Another portion of the Jackass Flats area has not yet been named, but was set aside for the future testing of experimental reactors.

In early 1957, the nuclear rocket propulsion project was re-studied from the viewpoints of national urgency, money requirements, and use of personnel and facilities. As a result, it was determined that the Los Alamos Scientific Laboratory was to continue with the programme related to nuclear propulsion of rockets (Project " Rover "), and Livermore was to continue with the programme for nuclear ramjet propulsion systems (Project " Pluto ").

The aim of the Los Alamos study is to determine the feasibility of using nuclear power to propel rockets, and to develop propulsion systems.

N-Energy Better?

The essential advantages are increased payload and an essentially inexhaustible source of energy. Design comparisons have shown that even the relatively unsophisticated solid-fuel reactor rocket system compares favourably with the best that chemical systems can do. Staff members at Los Alamos feel that nuclear propulsion systems toward which they are working have many advantages over chemical systems for vehicles designed to escape from the earth's gravity field and travel in space.

Project " Rover " work at the Los Alamos Scientific Laboratory is performed by several of the divisions of the laboratory, with most of the design work concentrated in N Division, which was formed for this purpose.

Approximately 120 members of the laboratory's technical staff are devoting full time to the project. Leader of N Division is Raemer E. Schreiber. Alternate division leader is R. W. Spence. Supporting groups at Los Alamos aiding with the " Rover " programme are those interested in high-temperature research, chemical and metallurgical research, fluid dynamics, neutronics, control analysis and mechanical design.

Flightless Tests

Nuclear rocket propulsion studies at Los Alamos are still in the research and development stage. Information gained from Nevada static ground tests is expected to help in formulating more advanced design concepts which may lead to construction of prototype nuclear propulsion engines for rockets.

Los Alamos is working only on the rocket propulsion systems, and not on the vehicles they would propel aloft.

First hook-up of the experimental test device, known as " Kiwi-A," took place recently, when testing of connections and instrumentation began. Cold assembly tests at the Nevada Test Site are scheduled for the near future. The point has not yet been reached in the feasibility studies for estimating the calendar date for initial hot assembly studies.

" Kiwi-A," which was designed and developed at Los Alamos, refers to the flightless New Zealand bird, which gives a clue to its purpose—it is an experimental reactor *not* designed to fly and not necessarily having flyable characteristics.

Approximately £3,460 for Phase 1 and £3,460 for Phase 2 have been committed for " 400 " area construction, most of this through open bid, fixed cost contracts.

Under development are three major groups of buildings and facilities, with supporting roads, water wells and lines, smaller buildings, railway trackage, electrical power supply feed lines and transformers, and a tank farm.

Following are facts on the three areas being developed, and status of construction:

The reinforced concrete control building, with a floor area of 9,700 sq.ft, houses the controls and instruments for operating and recording tests to be performed in the Test Cell area described subsequently. Other buildings in the same area, including a generator station for standby power an administration building, two warehouses, a cafeteria, and a small guard house, are constructed of steel and aluminium components so they can be moved if needed elsewhere. J. A. Tiberti Construction Co. of Las Vegas built these facilities for nearly £310,000.

The MAD House

The maintenance, assembly and disassembly building is a massive concrete structure (known as the MAD building) with 30,000 sq.ft of floor area where work will be performed, as indicated by the name, on assembling and disassembling reactors and their components before and after tests. Located nearby is a

small office and warehouse building, and a guard station. Sierra Construction Co., Inc., of Las Vegas is contractor for the building for nearly £745,000. The assembly side of the building is completed, but a hot cell addition will come later. J. A. Tiberti Construction Co. of Las Vegas is contractor for the hot cell addition for nearly £90,600.

Remote Controlled Loco

The test cell itself is constructed of reinforced concrete, with a floor area of 1,680 sq.ft. Reactors and reactor systems to be tested will not be housed in the cell, but will be supported on a railway car backed up to the cell. The reactor will be connected to a receiving instrument inside the test cell, which will transmit needed information to recording instruments in the control building about two miles away. The railway car bearing the reactor is moved by a remotely controlled locomotive over a railway line to and from the MAD building. Also being constructed in the test cell area are water storage and other facilities. Contractor for the test cell and tank farm is the Petroleum Combustion and Engineering Co. of Los Angeles, for nearly £470,000. Pittsburgh-Des Moines Steel Co. of El Monte, California, was the contractor for the water storage tanks for nearly £38,000.

Ramjet Studies

Project " Pluto " is the name given to the study being made by the University of California's Radiation Laboratory on the feasibility of applying heat from reactors to ramjet engines.

Ramjet engines using conventional fuels have achieved high speeds in trial flights. Their principle is that of compressing air very rapidly in the engine by attaining high speed, then heating it so that it expands on its passage through the engine and is ejected at a higher velocity to achieve the thrust necessary for sustained flight. The ramjet has been described as a " flying stovepipe." The principal drawbacks of such engines using conventional fuels are the initial difficulty of gaining enough speed to make them function, and their tremendous fuel consumption and consequent short effective range.

If a nuclear reactor were used to heat the inrushing air, the heat could be sustained over a long period of time, and the vehicle could be airborne for a correspondingly long period.

A ramjet can achieve thrust only within the earth's atmosphere, as contrasted with a rocket, which can travel in free space.

Experimental and theoretical work on the feasibility of applying heat from reactors to ramjet engines has been conducted at Livermore since early 1957, and the studies will be extended to the U.S. Atomic Energy Commission's Nevada Test Site.

Missile Work

The work, under the direction of Dr. T. C. Merkly, leader of the R Division of the Laboratory, is related to research on propulsion of missiles.

Also associated in the programme is Atomics International, a division of North American Aviation Co., Inc., at Canoga Park, California, where basic research into reactor materials is being conducted.

In studying the possibility of using a high temperature, gas-cooled reactor as a source of heat for ramjets, scientists say that the information developed will be useful in developing reactors for power production.

Costs Over £¼m.

Nearly £313,000 is being spent on construction and equipment for Phase 1 of Project " Pluto." Construction of facilities for high-temperature critical assembly is now about 85 per cent. completed.

A second construction phase is planned for Project " Pluto." This planned construction would include facilities for testing complete reactor assemblies, the disassembly of spent reactors, and miscellaneous support facilities, including road, a railway spur and utilities.

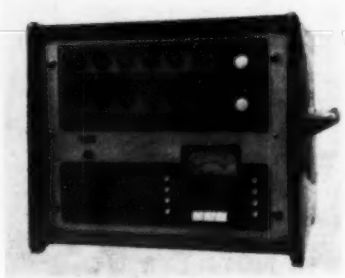
A mock-up of the " Kiwi-A " experimental reactor that will undergo tests in Project " Rover " is shown in this picture on its rail car outside the maintenance, assembly and dis-assembly (MAD) building

Equipment and Materials

Items published in this special feature are compiled from manufacturers' current literature. Readers requiring further information should use the form at bottom of the page. Manufacturers are invited to send literature or details of their products for inclusion in this feature.

New Scaler

The Isotopes Developments, Ltd., Scaler Type 1700 is a comprehensive, self-contained counting equipment for laboratory, medical and industrial uses. Add on a G.M. tube or a scintillation counter, and it can be used for almost any type of nuclear pulse counting. In the hands of the expert it is a flexible, accurate equipment; in the hands of a junior assistant, it is just as accurate and almost foolproof. The method of construction and the use of plug-in printed circuit boards make it an easy equipment to keep in service. Features include a fast scaler with nine pre-set count positions, electronic timer with nine pre-set time positions, triple range ratemeter with long and short time constants, single channel pulse height analyser, 250v to 2,000v stabilized high voltage supply, a linear amplifier sensitivity of 5mv-50v, connections for G.M. tube, scintillation counter or direct operation, power supplies for external head amplifier or quench unit, connection for operation of a mechanical printing register, connections for remote "Start," "Stop" and "Reset" operation, and connection for recorder for use with



IDL Scaler Type 1700

ratemeter. The unit has a tilt-up stand fitted for convenient viewings. Main functions can be push-button selected, and infrequently used "setting up" controls are concealed behind hinged flap on front panel. The designers of the scaler set out to produce an equipment with a performance to satisfy the most particular user. **(MAR 1).**

Portable Warning

Radiatron, of Richmond, Surrey, make a portable ionization chamber type of radiation warning instrument which reacts to a gamma dose of 30 milliroentgens. It is battery operated, pocket sized and weighs 12½ oz. It also responds to beta rays. Headphones may also be plugged into the Monitor. The instrument uses transistors and is also suitable for outdoor operation in temperate climates. The batteries have a capacity of 200 MA/hr and as they are discharged only during the emission of the signal and no current is drawn during measurement, they provide for two to three months' operation under normal conditions. They are recharged *in situ* by means of a small mains operated charger which weighs only a few ounces and can be plugged into the instrument. The Monitor has a flat response to radiation energies ranging from under 100 kV to 3 megavolts, an important

Radiatron's portable ionization chamber

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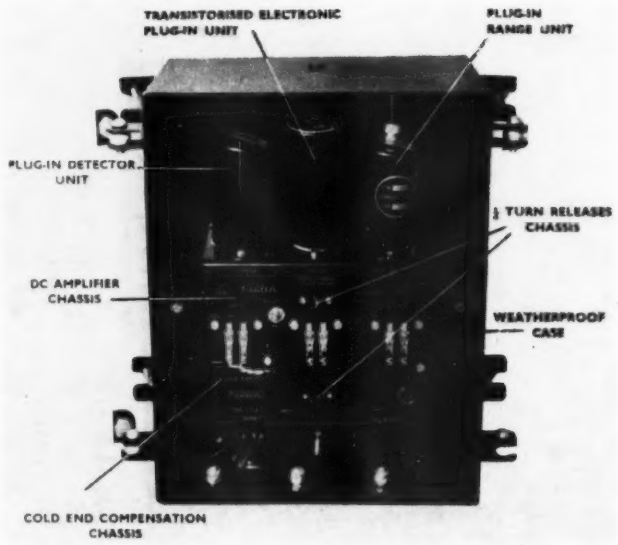
consideration as in most cases the radiation is composed of various energies owing to Compton scatter. It is a useful supplement to the pen type dosemeter which measures the cumulative dose received by the worker, as it gives early warning of a rise in the dose rate. The instrument is calibrated with its own calibration source. This is a small beta source normally housed in a lead-lined container. It enables the operator to check correct operation of the instrument by placing the source in position on the Monitor. For this he uses a stop watch and a calibration sheet supplied with each instrument. Similar instruments operating on a higher dose than 30 mr can be made for special requirements. **(MAR 2).**

For Temp. Measurements

Fielden Electronics Ltd., have announced a new equipment for temperature measurement using thermocouples. This equipment utilizes their new series of d.c. amplifiers which have been designed in close consultation with some of the larger instrument users in this country. The amplifiers, which can be supplied in ranges as sensitive as 2½ MV or 50°C. full scale, are accurate to as thin as 0.25 per cent. of the range. The new equipment is fully potentiometric in operation and calls for no current from the thermocouple to make its measurement, thus it is independent of the length of lead used between thermocouple and instrument within operational limits. The output circuit is completely independent of any resistance change within wide limits and, therefore, the calibration is completely unaffected by the resistance of the transmission leads. The equipment is stable to variations in supply voltage within ± 15 per cent. The unit operates off 12v d.c. resulting in inexpensive and safe wiring installation; it also satisfies the requirements for operation in hazardous areas. It consumes only 1 MA in excess of the transmitted current, thus it is economical in operation and can, if required, be powered from a small battery for long periods. On certain installations this feature is most useful. For example it means effective instrumentation in spite of power supply failure. It is possible to transmit over, say, telephone lines from remote points where a power supply is not available.



Fielden's equipment for measuring temperatures using thermocouples

The instrument is calibrated by a plug-in calibration unit and the range of any instrument can be changed in a few seconds. The electronic circuit is in a sealed container. **(MAR 3).**

New Diode

Considerable time has elapsed since English Electric Valves announced the E.E.V. germanium diode, type VA713. Since then this cell has found many applications in various industries, where it has given faultless service and demonstrated superior qualities of reliability, long life, and high efficiency. To enlarge the range, E.E.V. now offer the VA719, which is dimensionally the same as the VA713 (except for a slightly larger negative connection) but has an increased current rating of 20A at 35°C. It is available either as a single unit, or in multiple units fitted with fins and assembled into a stack. As a result of this new development, E.E.V. germanium rectifier stacks can now be supplied having maximum outputs as high as 130 amp. at up to 223v d.c. **(MAR 4).**

Book Review

Sodium Graphite Reactors, by Chauncey Starr and Robert W. Dickinson. Published by Addison-Wesley Publishing Co., Reading, Mass., U.S.A., 288 p.p. Price 52s.

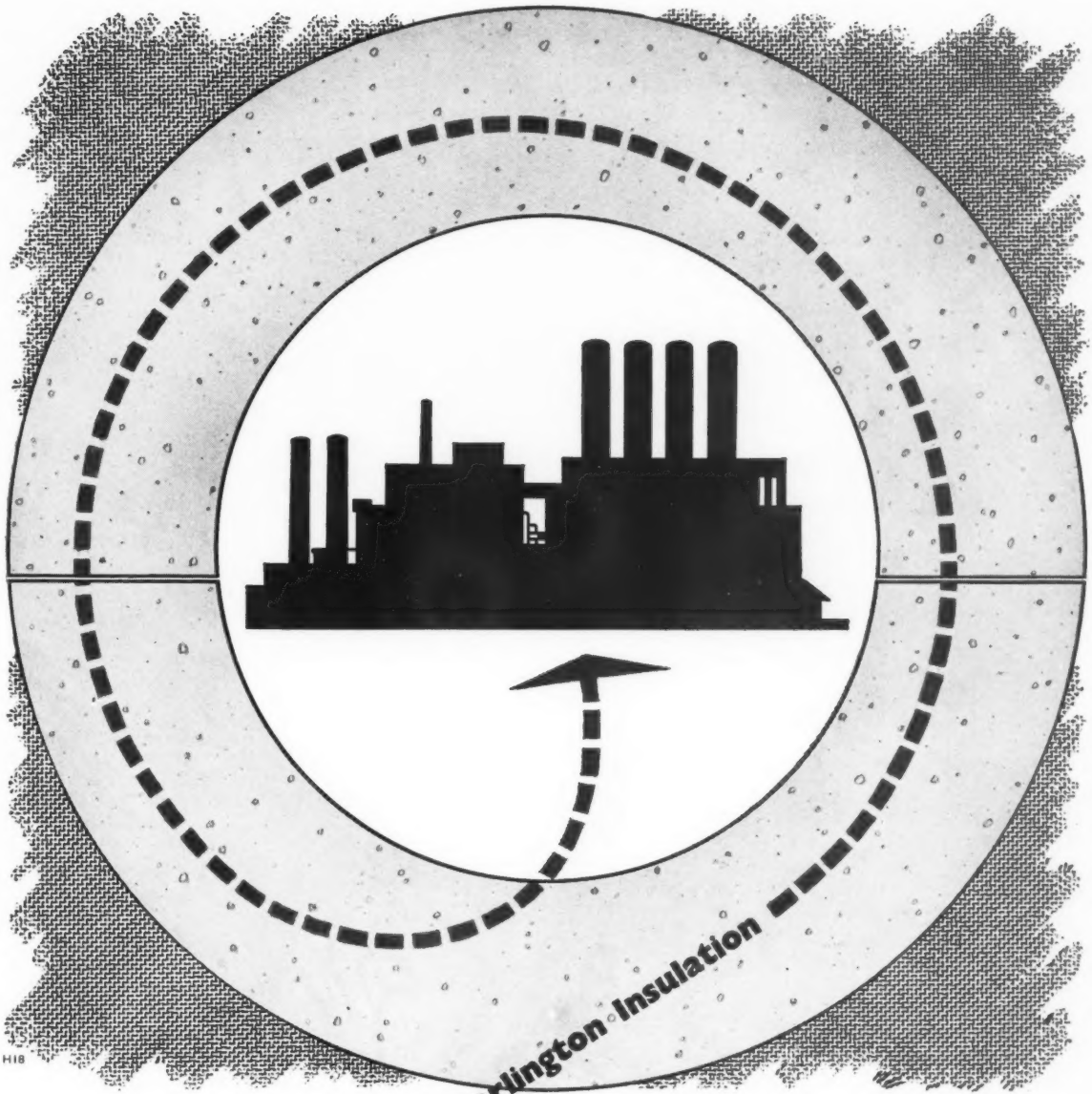
British scepticism on the possibility of the sodium-cooled, graphite-moderated reactor for large-scale, economical electrical power production makes it even more necessary to keep a sharp watch on the American work on this type of system.

In 1949, North American Aviation, Inc. were asked by the USAEC to study the sodium-graphite reactor, and the possibility of using slightly enriched fuel from 1950 onwards made the concept even more attractive. Plant construction started in April, 1955, and was completed in February, 1957, criticality being reached on April 25th, 1957. Full power was achieved by the SRE in May, 1958.

This report on the project, and its subsequent development, does not gloss over the many difficulties encountered. The concept, it says, is basically sound, and because of the ability of the system to produce good quality steam at reasonable cost, the future is bright. The reactor is characterized by excellent flexibility and stability. The authors, both very intimately connected with the work, and with an inside knowledge of all its aspects, give us in this book the full story. They deal with the inherent advantages and disadvantages of this type of reactor and the problems of power conversion, then consider the technology and development of every component of the reactor system, shielding, cooling, fuel handling, inert gas system, waste disposal, etc.

The first reactor of this class to be used for large scale operations will be the 75 MW (electrical) station at Hallam, Nebraska. A comparison of this with the SRE is made. It is confidently expected that for reactors supplying at least 100 MW of electrical power, the cost of the power should be no more than 10 mills/kW/hr.

Those who have watched with interest the development and commissioning of the SRE will be glad now to have this book, which gives them in compact form the whole survey of the subject, written in very readable style. **F.R.P.**



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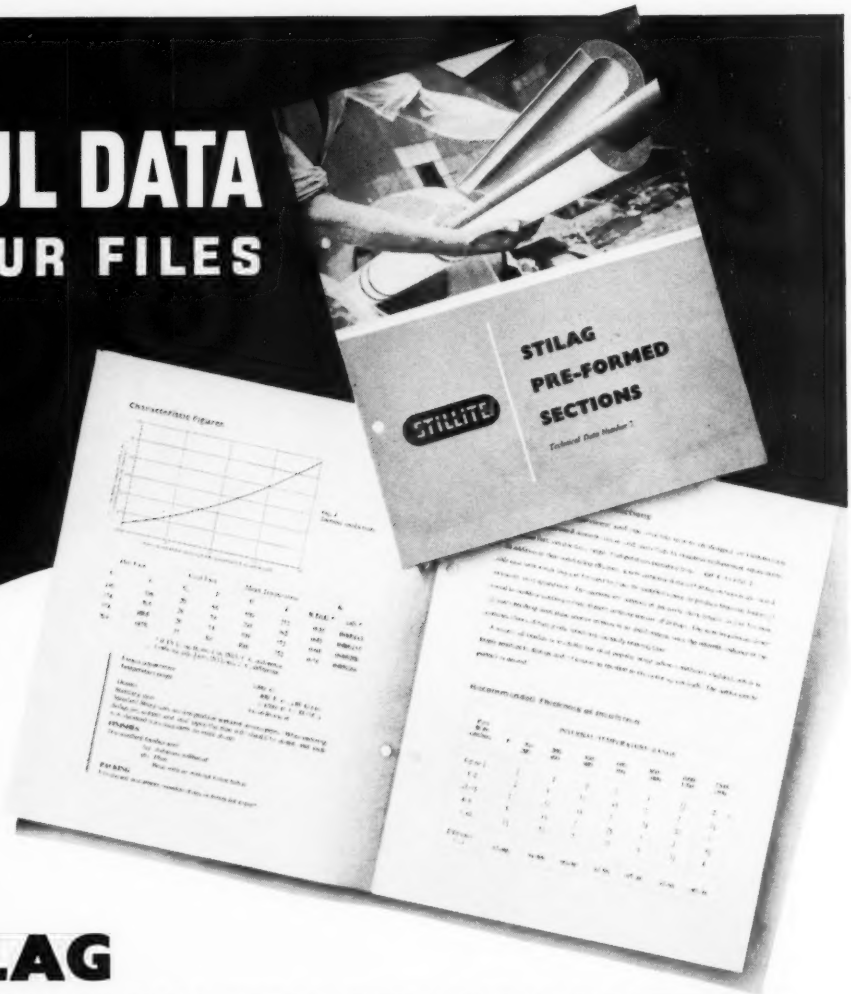

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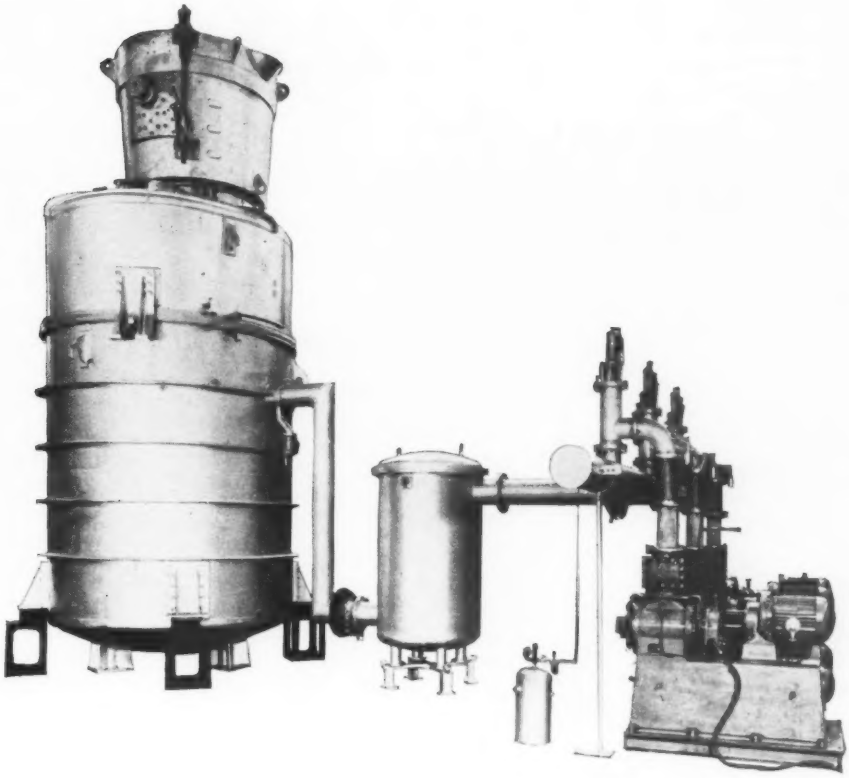

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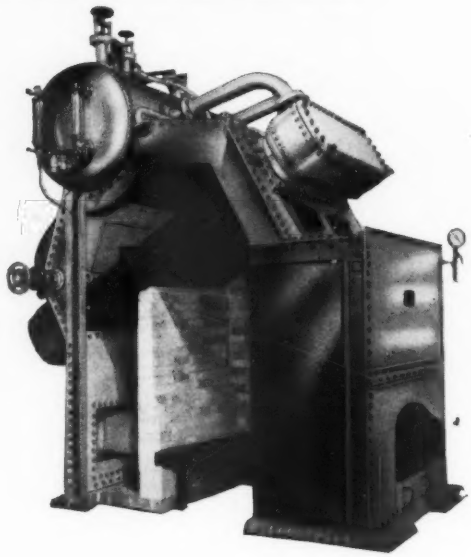

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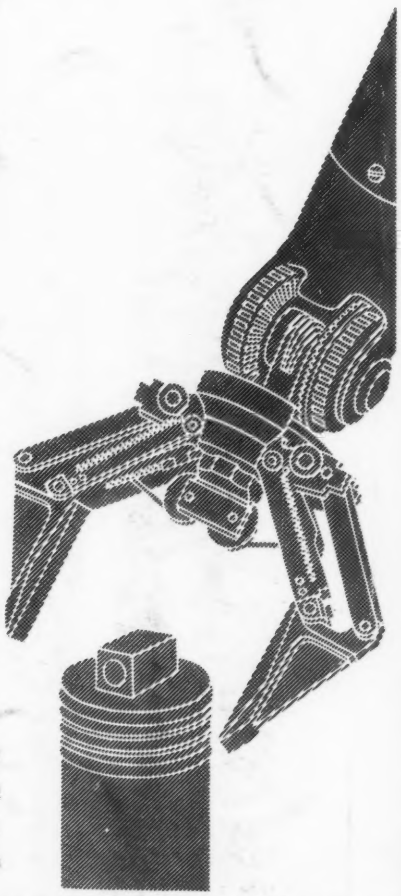

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